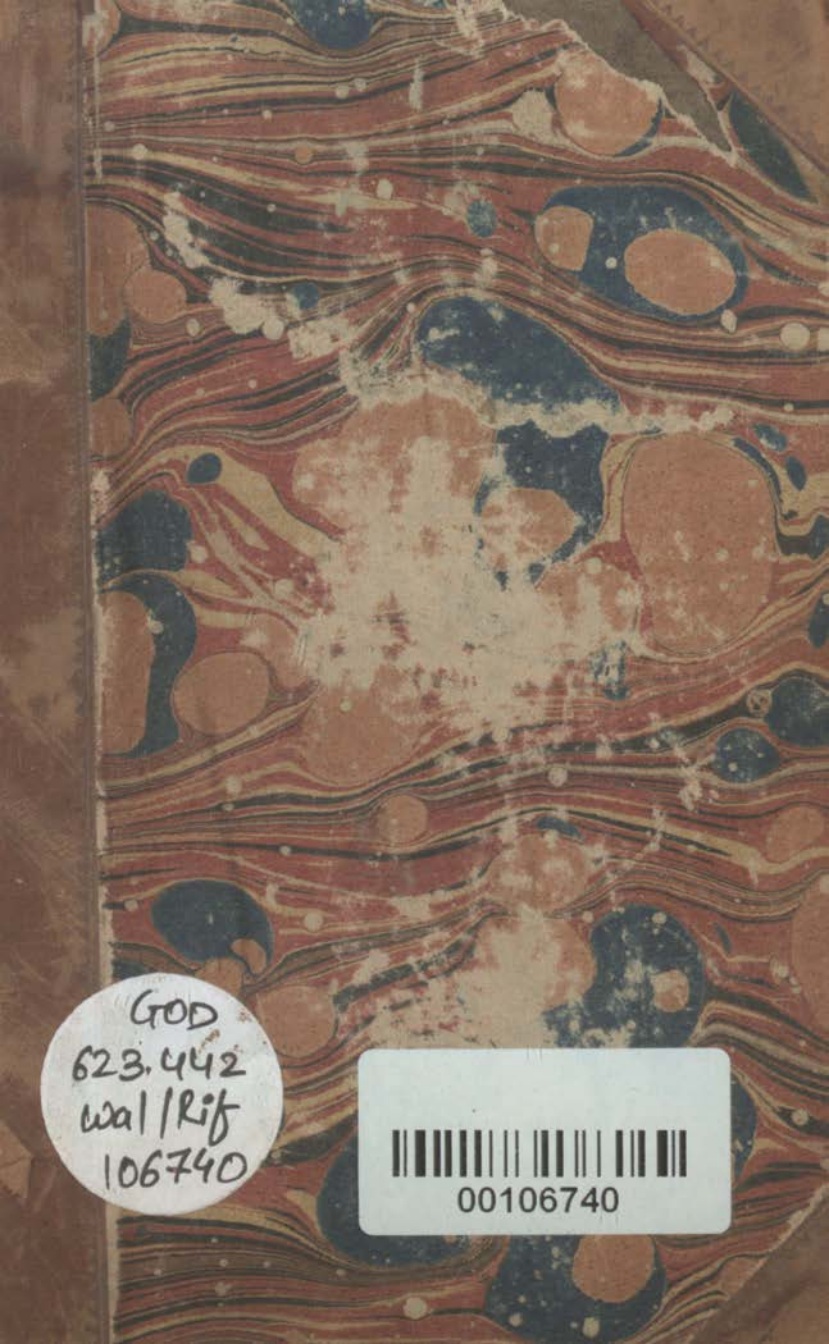
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THE RIFLE;

ITS THEORY AND PRACTICE.

BY

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CELER ET CERTUS.

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TO

THE LORD ELCHO, M.P.,

LIEUT.-COL. COMMANDING, LONDON SCOTTISH RIFLE VOLUNTEERS,
PRESIDENT OF THE NATIONAL RIFLE ASSOCIATION,

AND

ONE OF THOSE TO WHOSE PATRIOTIC EFFORTS THE SUCCESS
OF THE VOLUNTEER MOVEMENT IS MAINLY DUE.

PREFACE.

It may almost appear a superfluous undertaking to add, however slightly, to the large amount of printed matter which has lately been published on the subject of Musketry. But, notwithstanding this apparent pre-occupation of the field, there has seemed to the Author something still to be supplied: and, having been frequently asked for the Lectures which it has been his privilege to deliver to successive audiences at Hythe and Fleetwood, he now ventures to publish them, in the hope that they may be found useful to Musketry Instructors and Riflemen in general.

The latter will, it is believed, find in them somewhat of interest, whilst the former may derive assistance from them in the preparation of the prescribed series of Eight Lectures which forms a part of the annual course of instruction.

The Author has not considered it necessary to confine himself entirely within the strict boundaries of the subject, but has availed himself of any material which seemed likely to relieve its dullness or lessen its difficulties; and he has endeavoured in all cases to select the surest guides to the attainment of the end he has had in view, namely, to present as complete a *resumé* as the space of a moderate volume would permit of the present state of the Art of Musketry and the system of Instruction as sanctioned by the Authorities.

A. W.

Fleetwood, December, 1863.

*** The Author has to thank "The Royal United Service Institution" for the use of the woodcuts for figures 14, 36, 37, 38, 39, and 43, the original drawings for which were contributed by him, with a paper on Rifle Trajectories, to the Journal of the Institution, vol. vi. 1862.

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INTRODUCTORY LECTURE.

The Weapons of Man and Animals—Necessity of Training—Results of Musketry Training—Comparative importance of Drill and Musketry—The French system of Instruction—Importance of Preliminary Drill—Cleaning of Arms—Theoretical Principles—Aiming Drill—Position Drill—Snapping Caps and Blank Firing—Judging Distance Drill—Manufacture of Cartridges—Ball and Judging Distance Practice—Object and Social Effects of Musketry Training.

BEFORE proceeding to consider the rudiments or principles of the simple Theory of Musketry, according to the Red Book of Instruction for the Army, it may not be altogether devoid of interest or unprofitable to take a rapid glance at the offensive and defensive weapons with which man and even some of the lower orders of animals are provided; and then to examine briefly some of the causes which have led to the establishment of Schools of Musketry, and their system of teaching.

I. In contemplating the animated creation a striking fact arrests our attention—that the immense majority of animals on the land and in the sea are provided with the means of offence and defence. A state of perpetual warfare of the intensest kind—war for subsistence—exists among them, carried on by means of weapons of offence and appliances or

modes of defence admirably adapted to their wants and circumstances.

If war be not "man's natural condition—peace the exception," as D'Israeli epigrammatically averred, it is certainly that of the lower animals.

As a mere animal, man stands but a poor chance in his antagonism with some of his competitors in the lower ranks of creation; but his wonderfully characteristic brain has enabled him to place them all at a disadvantage; and, although his obvious destiny is to replenish the earth and multiply his own species, yet, as observes Alexandre Dumas, "with the aid of the Devil he has invented a thousand modes of destroying it."*

In doing so, however, he is but an imitator of his humbler brothers in creation. His modes of offence and defence are clearly analogous to theirs.

II. First. The effect of a blow of his fist or of his club may be compared to that inflicted by the head of a ram, the trunk of an elephant, the hoof of a horse, the wings of certain birds, the tail of a crocodile. Moreover, the Negro uses his massive skull precisely like the ram.

Secondly. The tusks of the elephant and those of the

* Perhaps Dumas borrowed this idea from Milton, who in his "Paradise Lost" ascribes the invention of gunpowder and cannon to the Devil and his angels in their war with the powers of Heaven, Satan being represented as

> "in hollow tube
> Training his devilish enginery;"

And the narrating angel thereupon saying to Adam—

> "Yet, haply, of thy race,
> In future days—if malice should abound—
> Some one, intent on mischief or inspired
> With devilish machination, might devise
> Like instrument to plague the sons of men
> For sin—on war and mutual slaughter bent!"
>
> *Paradise Lost*, b. vi.

boar, the horn of the rhinoceros, the horns of the bull, the canine teeth and the claws of the carnivora, the quills of "the fretful porcupine," the peculiar weapons of the saw-fish and the sword-fish, are all designed and intended for thrusting, just as are the dirk, the poignard, the spear, and the bayonet of man.

Thirdly. Bees, scorpions, and venomous serpents inject poisonous matter into the wounds they inflict; so does man with his poisoned arrow.

Fourthly. Monkeys, bears, ostriches, giraffes, and even seals, when pursued and hard pressed, are said to dash stones at their pursuers; and, still more wonderful, naturalists tell us of a little sporting fish whose skill as a marksman is truly extraordinary. This little sportsman rises near the surface of the summer sea of China and its latitudes, just where the flies or other myriad insects are unconsciously vaulting in their mazy dance, and, taking his aim, ejects unerringly at a fly a small pellet or drop of water, bringing it down, and so "bagging," or at least swallowing, his game.

Thus it appears that man is not alone in his efforts *to kill at a distance*. His dart, his spear, his javelin, his wondrous boomerang and deadly assegai, his slings, his arrows, his primitive matchlock, blundering blunderbuss, and cumbrous cannon—emerging into the all but perfect gun and rifle—are only contrivances in accordance with the natural instinct which man shares with other animals.

III. If these considerations lead us, as usual, to the conclusion that "there is nothing new under the sun," we must still bear in mind the arduous difficulties which man's brain has had to overcome before he attained what Kinglake, in his Crimean History, describes as "the methods of high organization and ingenious contrivance now brought to bear

upon the structure of armies," and before he could fashion the metals and apply the "villainous saltpetre" so as to produce that magnificent means of offence and defence—the rifle of the present day.

IV. But, just as highly-improved machinery involves increased intelligence on the part of the mechanic and engineer, and as the introduction of steam ploughs and reaping machines in farming necessitates a superior description of agricultural labourer, so, in like manner, the universal introduction of the rifle into our service required, on the part of the soldier, a certain amount of knowledge which could only be imparted to him by means of a special training.

On the other hand, however, it would almost seem from what one hears daily, that every man considers himself a "heaven-born" rifle-shot, just as every man is said to believe he can drive a gig; but no idea can be more erroneous or absurd. It would be just as reasonable to assert that every man is able to fence, or to ride a horse like a dragoon, without any training. Yet from time immemorial we have had riding and fencing schools in our service; while the French, in addition to these, have their "School of the Soldier," "School of the Company," "School of the Battalion," "School of the Skirmishers"—such at least are the titles of the respective divisions of the French "Instruction" for their army; and they accurately indicate their method of treating their soldiers as *pupils*. To enable a man to defend himself, he is made to undergo severe training during the first year of his service, and is forced to attend the fencing-room five times a week. When the *prévôt d'armes* judges him sufficiently instructed, he undergoes an examination before the colonel and staff; he is then expected to combat any adversary the colonel may select, and defend himself not only from the sword, but the bayonet and the lance. Our

"Rifle Practice," with its emulative combats at the butts, forms now a sort of counterpart to this in our service.

Without training it is impossible to enable a man to handle or use any instrument with the requisite accuracy and advantage, and certainly not that wonderfully-made instrument the rifle. Hence the institution of our establishments at Hythe and Fleetwood, as normal schools, to supply the entire army with an efficient staff of musketry instructors.

V. Before the foundation of these establishments, there had been no recognised *method* of teaching men to shoot. Of course, there have always been here and there men skilled in the art of shooting; but in the army such men were very rare; and it might truly be said that the army as a whole could not shoot; indeed it hardly pretended to do so. It is notorious that not one man in a thousand of Wellington's troops had ever learned to shoot; and it was held that out of 250 bullets fired 249 were thrown away.

VI. The modern improvements in small arms have, however, changed all this and completely altered the case. The rifleman of 1863, dealing death at a distance of 1,000 yards, is a very different being to the soldier of 1800, with his musket killing once out of 250 times, at a distance of 100 yards. When Lord Hardinge substituted the Enfield rifle in our army for old "Brown Bess," the effect of the change—according to the dictum of Sir William Napier—was at once to render the fire of infantry soldiers at least four-fold more effective than it was formerly; provided always, however, that the training of the soldier in whose hands this weapon is placed has been such as will enable him to elicit its full power.

VII. Thus, assuming for instance that a soldier has the good fortune to belong to a regiment whose discipline is admirable, its drill all that could be wished, each company

a moving wall of animated muscle, so to speak,—assuming, further, that the regiment has been led into the presence of the enemy with all the consummate art of strategy and tactical skill of a Marlborough or a Wellington, so as to be posted at *the right time and in the right place,* for delivering their fire,—of what practical avail would all that excellence in foot-drill, and all that unrivalled precision in manœuvring be, if the majority of the men were unable to make any effective use of the weapon placed in their hands for the destruction of their enemy? There—separated by a few hundred yards, perhaps less, stands the mark, a massive living target; but, unhabituated to a good position, unaccustomed to measure the distance with his eye, and unused to his sight, he cannot hit that target. He throws away, high in the air, or low on the ground, the bullet which should be a "messenger of death;" or, worse still, perhaps from an ignorance of "cleaning of arms" and its requirements, his rifle misses fire, and he stands there like a dummy, to be shot down by the more skilled French chasseur or Prussian jäger, skulking Indian, daring Affghan, or even slouching Hottentot and agile Caffre!

This is no fanciful picture. Such a reality has occurred to the British army in America, at the Cape, in Affghanistan.

VIII. Against this, however, perhaps it will be urged, "Has not the British soldier his bayonet, his own peculiar weapon, to depend upon?" Yes, truly he has, and far be it from me to disparage the well-known effect of a British bayonet-charge; but then "two can play at that game;" and what happens if the naked savage, the light-clad Affghan, the athletic bushranger, the nimble chasseur, or the hardly less expert jäger, decline to be saluted with "cold steel," and prefer stealing away to a respectful distance, and again winging a deadly hail-storm of bullets?

IX. Now the common soldier of our army can be taught to handle a rifle, just as other men are taught to guide the steam-plough or to superintend a steam-engine; he can be made as careful of his ammunition as a farmer of his grain, and learn the construction of his piece as easily as apprentices learn the arts of watch-making, ship-building, or any other trade; in fine, he can be made a rifle-shot. In proof of this, there are in the army at the present moment 32,784 "first-class shots," that is, men qualified to shoot effectively at all distances up to 900 yards; there are 66,783 "second-class shots," or men qualified to shoot at all distances up to 600 yards; while there is a total of 121,423 men who have undergone a thorough training in the use of the rifle in individual, file, volley, and skirmishing firing, at distances within and up to 400 yards.*

Of course the greatest enthusiast in the fascinating science and art of musketry never for a moment imagined that battles would henceforth be decided—so far as infantry are concerned—at distances *beyond* 300 or 400 yards; but it is clear as noonday that if a soldier can shoot with precision at distances of 800 or 900 yards, *à fortiori* his fire at 200 or 300 yards will be doubly effective; the first involves the second as a natural consequence. Moreover, by becoming a "first-class shot," the soldier acquires confidence in his weapon, a matter of no slight importance; for, according to a civilian well qualified to form a practical estimate,† "the moment a man becomes quite certain that he can kill whatever object of his own size may be within 500 yards of him if he chooses to pull the trigger of his rifle, he has acquired a stock of self-knowledge which, in a military sense, multiplies his value many times over."

* Appendix A, Returns of Musketry Instruction, p. 24.

† Dr. W. H. Russell on Rifle Clubs and Volunteer Corps.

The warmest advocates of rifle-practice have never confounded, as has been asserted, target-practice with practice in the field; it would indeed be simply absurd to suppose that a soldier would be able to fire, in the presence of the enemy and in the excitement and confusion of the battle-field, with anything like the precision achieved on the target-ground; but, on the other hand, will the scoffers at musketry instruction presume to say that the soldier who at pleasure can put in "bull's-eyes," "centres," or merely hits, at all the target-ground distances, will not be able, on that very account, to fling into the enemy a much larger per-centage of decisive bullets? To doubt this is tantamount to asserting that practice with his tools is of no use to the carpenter when he has to make a table, no use to the mason when he has to build a wall, and is contrary to all experience.

It may reasonably be urged here, also, as a set-off or counterpoise to the disadvantages riflemen have undoubtedly to contend with on actual service, that the human target presented in action is usually much larger than an iron screen 6 feet in height by 16 in width and with a depth of only about one inch and a half,—the dimensions of the target now made use of in the "file and volley firing" practices, which is supposed to represent the front of a section of 9 or 10 men, who when accoutred in the field present about the same height and width,—but posted in two ranks this human target presents a depth of at least 40 inches; moreover, it matters not whether we hit this target high or low, right or left, provided we *hit*. One man of the section will then at least be put *hors de combat*, and have to stagger or be carried to the rear, thus rendering either two or three men temporarily ineffective. So much for the enemy in line. But how immensely this human target expands when a company in fours, or a dense column at close or quarter-distance, stands before

us! What havoc a thoroughly well-taught regiment would make in firing at such a mark!

Or take for example the effect of the fire of a well-drilled and well-handled battalion if called on to resist cavalry. A horse will walk over 400 yards in about four minutes, trot the same in about two, and gallop it in one. A well-drilled soldier will easily fire two rounds a minute, and supposing an infantry square—of which the front consists, say, of 32 men, with two ranks kneeling and two standing, or in all 128 men—to open fire at a distance of 800 yards, during the time (taking it at four minutes) the cavalry traversed this intervening distance, the latter would receive 8 rounds from each man, so that no less than 1,024 Enfield bullets would be hurled against them. It is difficult to conceive how, under such circumstances, they could escape annihilation. It is true that as yet such contingent circumstances as are here indicated have never fully presented themselves in practice; but when they do so, as in the natural course of events they doubtless will, we venture to predict that practice and theory will not be so much at variance as is generally imagined.

X. It is proper to have a right understanding in this matter. What can be done by instruction and practice is obvious; and what cannot be done, in the absence of both, is equally obvious and undeniable. It is obvious, then, that a regiment, however well drilled and pipeclayed, which cannot when brought into action use its fire-arms effectively, is comparatively worthless, and resembles not a little a fine ship whose splendid equipment is rendered nugatory or useless by not having a single soul on board who understands the use of the quadrant or sextant and the principles of navigation, so as to steer her in the required direction:—"a soldier who cannot shoot is useless, and

an incumbrance to the battalion." On the other hand, it must be admitted with equal reason that a regiment, however skilled in the use of the rifle, without discipline and mobility, would not be unlike a vessel deprived of her rudder and her sails, a mere cumbrous log upon the ocean. At any moment such a regiment is liable to become a mere demoralized crowd of men in utter disorder.

XI. In fine, it must be always understood that target practice and bull's-eyes are worthless if unaccompanied by discipline in the *man*, and that mobility which caps the perfection of the *soldier*;* and that drill and field evolutions are so much time lost if in the end, when the actual tug of war comes, the men cannot use their rifles with effect.

Hence, we want in every regiment a good adjutant as well as a good musketry instructor; and a good musketry instructor as well as a good adjutant. Let us then proceed to consider how a good musketry instructor can be best formed.

XII. The system of instruction adopted at Hythe and Fleetwood has for its object the substitution of a thinking unit for the pipeclayed automaton of former days—in fact, the conversion of a mere human machine into a *taught* soldier, who, in the field of active service, whether with the main body of an army, or separated from it as in skirmishing, would still, by virtue of his special training, elicit the full power and capabilities of his rifle, and yet instinctively ap-

* "I am a rifle instructor and an old soldier, but I tell you this that all your shooting is not worth a straw unless you can drill and manœuvre. Combine your good drill with good shooting, and then you will be irresistible."—Extract from a speech by Col. Parke, C.B. &c., Chief Instructor, School of Musketry, Fleetwood, to Lancashire Volunteers, Altcar, 1862.

preciate and conform to the general object of any manœuvre which is being performed.

Pupils at Hythe and Fleetwood are not addressed as mere soldiers, but as men endowed with an intelligent will, capable of development to a good purpose in the day of battle. For, is not the mind the rudder of a man? Does not a man most truly shoot with his *mind*—his bodily members being merely the servants of that mind? And, regarding the soldier as a being with a mind, he is given the *reasons* for the rules he may afterwards be called upon to adapt in practice.*

In this it is true we only copy the French, who have long made their soldiers (and they have made some of the best in the world) by appealing to the common sense of the men, and by explaining "the reason why" to them for almost everything they are called upon to do. Amongst other things of a like kind, for example, the young soldier has on first joining to attend a kind of lecture, which is given weekly to each company, the object being to make the men fully acquainted with the code of military justice, the offences for which they will be punished, and the duties of a good soldier. The subject explained in the first lecture is "Faults against Discipline."†

The officer delivering this lecture makes many of the men in turns explain what they understand by the article in question, and helps them to demonstrate it by suggesting examples of such faults as a soldier is likely to commit, and how to avoid committing them. He cites examples of every-day occurrence, asks their opinions, and corrects any misunderstanding under which they labour on any point. "Really," says one who writes on this subject, having him-

* Col. Wilford.

† Chap. xxxvii. of the Code de Justice Militaire, art. 328.

self been a French soldier, "at the end of the lecture I had a clear understanding of the duties of a soldier."*

XIII. So much for the appeal to the understanding of the French soldier in "setting up" his *morale*. How is it in setting up his *physique*? Why, precisely the same. If, in our army, a recruit were to ask his drill-sergeant "the reason why" for anything prescribed for "the position of the soldier," the sergeant would most likely be struck dumb with amazement, and "give it to" the inquisitive recruit in any shape but that of an explanation. Now, it is otherwise with the French. The *reason* for every item of recruit drill must be given by the instructor, and in like manner throughout their drill-book the reasons are given for every thing the soldier is required to do, these explanations following every lesson, and forming really the most interesting portion of the book, in fact the *philosophy* of drill, admirably adapted to explain to the soldier the movements of the barrack parade and the formations and evolutions of a battalion.

For instance, the first injunction of the French "Position of the soldier" is "the heels must be in line." Why so? That is a simple question; but how many sergeants can answer it off-hand and correctly? It has never occurred to them to inquire into the *reason* of anything ordered; the thing *must* be done—that's all. Now, the French drill-serjeant is positively enjoined to explain to the recruit that the reason why he orders him to keep his heels in a line is "because, if one heel is in rear of the other, the corresponding shoulder would sink," and consequently the "exact squareness of the shoulders and body to the front" could not be secured. Indeed there is nothing about the squareness of the shoulders in the French drill-

* In a recent number of "All the Year Round."

book, simply because it must be the result of the heels in line—the effect following the cause. So, in like manner, they do not enjoin that the heels *must* be closed, but only *more or less* closed, and give the very simple reason, namely, because knock-kneed and stout-legged men *cannot* close their heels.*

XIV. In our improved method the general course of Musketry Instruction is divided into two distinct parts or heads—*Preliminary Drill* and *Practice.*

The former is the foundation of accurate shooting. For, startling as the assertion may seem, provided a man thoroughly masters his preliminary drill, we undertake to make him a "good shot" before he fires a single bullet. In other words, the efficiency or non-efficiency which he exhibits on the target ground is merely taken as a test of the attention which he has paid to the rudimentary details of the drill. One of the maxims of the School of Musketry is this: "We teach a man to shoot without a ball, and then we give him ball to prove what he has learned."

In his evidence before Parliament, General Hay says that "a man may be taught to shoot by drill alone, if he can but be taught to put faith in the theory. If a man will take your word for it, and do what you tell him, there is no doubt you may train him by drill. The reason why regiments do not shoot well the first year is, that they will not believe what you tell them. Precision of firing depends upon the drill. We have reduced it to a positive certainty. Our drill is simply to make a man, before he goes out to fire, understand the reason of everything he has to do in practice. Detect the error of a man, point it out to him and correct it, and that man becomes as valuable as any other as far as shooting goes."

* Instruction sur l'Exerc. et les Manœuvr. de l'Inf. Ecole du Soldat, tit. i.

It cannot be denied that this preliminary drill is somewhat irksome. In many of its requirements we are naturally apt to say to ourselves—What *can* be the use of all this?

Now, depend upon it, the chances are, if you ever allow that rebellious objection to lessen your efforts, you will never get out of the third class. This unfortunate and depressing result has happened repeatedly from this very cause. You must begin with implicitly taking it for granted that you should conform strictly to every point of the regulations, if you wish to become good shots. Call it, if you like, the pot-hooks and hangers of musketry. Be it so, but who ever learned to write well without beginning with pot-hooks and hangers? Bad hands are the rule, good hand-writing the exception, because the scrawlers did not *see the use* of, and therefore neglected, this important preliminary training.

Our system then, like Sir William Armstrong's gun, is based on the principle of "building up." Thus, under the head of DRILL there are eight distinct corner-stones, so to speak, of the building; and, if you take away any one of them, the general stability, usefulness, or efficiency of the structure becomes more or less weakened.

Let us cast a rapid glance at these eight corner-stones, or, if you like, eight links in the chain of preliminary drills, before entering on the special task assigned to us.

XV. 1.—*Cleaning of Arms.*—In this drill the soldier is taught the different parts of the lock, stock, and barrel, and how to maintain them and his ammunition in the highest state of preservation; for obviously it is just as necessary for a soldier to know all the component parts of the instrument he works with, as for a carpenter to understand the names and uses of his different tools. The construction and action of the lock are fully explained, so

that an intelligent soldier in the field may be, to a certain extent, independent of an arsenal or armourer sergeant, should his lock get out of order. And, if a spring snapped, he may replace it with one from another damaged rifle, from his acquaintance with the principle of interchange, upon which all the service rifles are constructed.*

Again, the proper pulling or rather the squeezing of the trigger depends to a certain extent upon his knowledge of the mechanism of his lock; whilst a dirty rifle is very like a blunt sword, both being unfit for the work intended. A soldier whose rifle misses fire in action, owing to the defect of his lock, or the presence of dirt or rust, through his own neglect, is a cumbrance to his regiment.

XVI. 2.—*Theoretical Principles.*—This branch of the instruction is in every instance specially confided to the Officer-Instructor of Musketry, whose duty is not merely to convey to his hearers in a clear and concise manner a knowledge of the physical laws which regulate the flight of the bullet, and the internal construction and mechanical action of his rifle, but he must also endeavour to interest the mind of the soldier in the subject of rifle-shooting generally, by supplying him with the reasons for all the details of his drill, so that some harmony may exist between him and his occupation ; and, on the principle that

"Who rules o'er freemen should himself be free,"

rifle instructors should be able to demonstrate to the outer world their affinity with their profession by being themselves good rifle-shots.

* By means of certain ingenious copying machines at the Enfield factory, and a rigid adherence to one pattern, all the different parts of the rifle, even to the minutest screw, are made so exactly alike, that any part of one rifle is precisely similar to the same part of another, and may be substituted or changed for it; hence what we call "the principle of interchange."

There is no doubt that a man may shoot perfectly well at a fixed mark without having any deep insight into the theoretical principles of shooting; but it is equally certain that an acquaintance with them is of great value in actual warfare. A ship may be navigated practically by a sailor who knows little or nothing about lunar observations, great circle sailing, and the other useful theorems of navigation; but would any one prefer sailing under such a captain rather than under one who had received a proper certificate from the Board of Trade? Again, we feel a much greater interest in visiting a country if we have first read up a little about it; and so it is with the art of rifle-shooting. On the other hand, whilst necessarily admitting that many have become good shots without any theoretical instruction, we contend that all their good shooting is mainly due to a compliance on their part with the stringent rules and regulations of musketry in the absolute essentials. By dint of hard practice, and great waste of powder, shot, and time, proficiency may indeed be attained; but it is our endeavour to make a good shot without waste of powder, shot, or time. This doctrine has been fully recognised, and has received the entire approbation of an authority so eminently practical as Horatio Ross, the veteran deer-stalker, who writes as follows:—"As the economy of time and ammunition is a matter of very considerable importance to most people, I therefore wish to assure them in rifle practice it is not necessary to fire a great number of shots. A man who makes *judicious notes of his practice* will derive more advantage from firing a hundred rounds than another who expends a thousand rounds without doing so." *What is this but recommending that theory should be to a certain extent combined with practice?*

XVII. 3.—*Aiming Drill.*—In this drill the soldier is taught to make a correct alignment with his sights at pro-

gressively increasing distances, his rifle being placed on a *fixed rest* for the purpose, just as artillery men are practised constantly in training at their guns. This exercise or eye-drill—if properly performed—not only has the effect of training the soldier readily and without hesitation to align his sights correctly, but it has, at the same time, the effect of strengthening the vision; for the eye, like the brain or the muscles of the leg and arm, is capable of being strengthened by judicious exercise in the open air. Very few men can aim correctly at first; and, even when able to do so at a short distance, they are unable to do so at any great distance, in proportion to which the difficulty increases. This can only be overcome by practice: hence the necessity for this drill. We have to *learn* properly to use a telescope; and yet the difficulty of this is nothing to that presented in rifle-shooting, where four things have to be brought into a perfect alignment,—the point or object aimed at, the tip of the fore-sight, the bottom of the notch in the back sight, and the eye.

XVIII. 4.—*Position Drill.*—This is practised with the view of *habituating* the limbs and the eye of the soldier to assume readily, under all circumstances, the best position for using his rifle effectively. The first part of it is simply a gymnastic exercise, calculated to develope the muscles of the arms and other parts of the body, and give the soldier a complete command over his rifle, so that he may manipulate or handle it with perfect ease; in fact it is a sort of preparatory training or club-drill.

In the *second* practice all the motions of actual firing are gone through in their proper order. The eye now takes aim, and the finger is taught to press or squeeze the trigger with what General Hay has defined as "a sleepy calmness," and which Colonel Wilford says should be done "as if you

had to squeeze *one* drop *only* from a sponge or orange." All this must be done with the same pains-taking precision as if actually firing bullets.

In the *third* practice the eye and hand are still further habituated to act in unison, so as to train the finger at once, without faltering or indecision, to obey the message conveyed to it by the eye through the will or brain.

With respect to this, Colonel Wilford says: "It is a most extraordinary fact that the great majority of men cannot pull a trigger when they like or when they ought. They feel that they pulled at the wrong time, and that the finger did not obey the mind;" hence the necessity for this practice.

With the view of actually testing the accuracy or inaccuracy of this dummy-shooting, the pupil is instructed to aim at the instructor's eye, so that any faults are thus practically discovered and corrected.

It cannot be denied that Position Drill is the most arduous part of the course—most trying and irksome throughout, if we do not heartily enter into it as a well-considered and admirably-designed method of achieving its most important objects. No one, however, should deceive himself on this score. He cannot do without Position Drill, accurately performed, even to get out of the third class into the second; and should he find himself remaining in the third class he will only have to regret that he did not enter heart and soul into his drill, in addition to the mortification resulting from his bad position in the Returns.

XIX. 5.—*Snapping Caps.*—In this and the next drill the recruit is gradually, as it were, introduced to the use of ball cartridge, the cap-snapping being designed to cure or diminish the habit of winking, and prevent that nervous start, causing a spasmodic jerk on the rifle at the fall of

the hammer. Many recruits positively shut their eyes completely before firing,—with what results can be easily imagined.

XX. 6.—*Blank firing.*—This forms a natural sequence to the preceding drill, being designed still further to accustom the recruits to the jar caused by the detonation of the cap and explosion of the powder, so as to prevent the steadiness of aim being influenced by the recoil or "kick" of the rifle, which, unless neutralized by a good position, is likely to be anticipated by the recruit, after a first trial, in such a way as to render all the rest of his instruction and training utterly useless. Sportsmen have long recognised the utility of thus habituating the uninitiated to fire at first without having shot in the gun; and it is much to be feared that the inability to resist this "kick" of the rifle is a great cause of bad firing by soldiers. Yet certain it is that no one is kicked by his rifle if he holds it properly, and stands in a proper position, as taught by the regulations. If you hug your rifle as you would hug a big bully to prevent him from pitching into you, depend upon it the rifle will be as harmless in your hands as the aforesaid individual, or a slumbering babe.*

XXI. 7.—*Judging Distance Drill.*—This drill is of the utmost importance, as shown by its ultimate object. The whole theory of musketry is based on the laws that require us to raise or give elevation to the muzzle of the rifle, according to the distance of the object we have to hit. The rifle is provided with properly-adjusted back-sights for this very purpose, to enable us to shoot from 100 up to 1,000 yards. Now, unless we are able to form a correct estimate of the distance between us and the enemy, of what use will be our back-sights—of what use our firing?

* Appendix B, p. 25. Theory of Recoil.

XXII. 8. *Manufacture of Cartridges.*—Every recruit is taught how to make up a cartridge. It is said that the defence of Lucknow was greatly aided by a soldier having been instructed in this operation ; and it stands to reason, in view of the thousand-and-one emergencies of actual warfare, that every soldier should, on a push, be able to make up ammunition for his rifle. Twelve men at least in each company are to be practised annually in this cartridge-making.

It need scarcely be stated that special times are set aside for the practice of these drills.

XXIII. We now come to the more exciting part of the business, the Practice, which may be briefly summed up as consisting in every drilled soldier expending annually ninety rounds of ball ammunition, in the following manner:—

60 rounds in individual firing,
10 „ in file firing,
10 „ in volleys, and
10 „ in skirmishing or extended order.

The details of these practices are so fully given in the Red Book of Instruction, that it would be useless to expatiate on them here. It will suffice to state that every shot fired is registered, so that, if a man fire badly or carelessly, he is sure to be detected, and will permanently transmit to posterity the records of his misdeeds.

Throughout the country, nay, throughout the world, the army, the militia, and the volunteers, go through this course of regulation practice, or class firing, at the same sized targets, the same sized bull's-eyes, and at the same distances, and the points are registered on the same scale. The points scored by an individual, a section, a company, or a battalion, are ascertained to a decimal. There is no possibility of vain boasting, for all is reduced to what is termed "the figure of merit." By that we must be pre-

pared to stand or fall. By that the Government and the country can discover annually and proclaim, so to speak, the *war power* of the nation. By that foreign governments will know how to estimate our power of defence or attack, and "inly ruminate the danger;" whilst *we* may, indeed, be permitted to "pluck comfort from its looks."

Here is what constitutes this figure of merit, achieved by the British army for the year 1862–3.

Average points obtained, 1st period:—

From 150 to 300 yards, 20 rounds	15·89
File firing at 300 yards, 10 rounds	10·60
Volley firing at 400 yards, 10 rounds	8·71
Skirmishing between 400 and 200 yards, 10 rounds	4·88
FIGURE OF MERIT OF THE ARMY	40·08

XXIV. Judging Distance Practice goes on contemporaneously with target practice in its different stages; and from its registers we can at any time, in every regiment in the service, estimate that essential element of effective firing in the British army; so that, for any given purpose in a campaign, requiring skill in this department of musketry, the general can at once select both officers and men the best qualified for this important function.

XXV. Such then is a brief sketch of the musketry training as originally instituted by the French in their *Ecoles de Tir* or schools of musketry, at Grenoble, St. Omer, Toulouse, and Vincennes, and introduced with a few important modifications into this country in the year 1853, under the auspices of Lord Hardinge, the great benefactor of the British service. The French have suppressed all their other schools of musketry, retaining only that at Vincennes; whilst in England we have recently organised another at Fleetwood, precisely on the same system as that at Hythe,

to meet the requirements of the service; in accordance with the conviction, now completely established, that, without adequate instruction and training in the soldier, the rifle must be as useless as the old discarded smooth-bores of our fathers.

At the French school of musketry only officers are instructed, whereas at Hythe and Fleetwood both privates and officers are trained together, and with obvious advantages. The officer at once applies his knowledge, learns the method of instruction, familiarises himself with the details of the business, *works with the men*, and thus becomes master of his art, not without some salutary experiences, which prove that, if he necessarily excels the private in certain points, he is only second to him in others—a powerful incentive to that kind forbearance so essential to an officer.

XXVI. On perusing the sketch of musketry instruction here given, perhaps the question will occur to the reader whether after all is said and done, when we reflect on the many things to be observed and attended to, when we consider the nature of the training required for the full development of the rifle's power, the study and attention requisite to appreciate its mechanical construction and use—it is wise to entrust so delicate an instrument to the hands of the rough and careless soldier. Is it to be expected that in a campaign or a battle the rifles will be invariably clean, and the sights always accurately adjusted and aligned?

We admit at once that this cannot be expected. A rifle must be in a state of perfect order before it can give perfect results, but even imperfect results have their own value. Nobody expects that every shot fired by every marksman will always fly as true as the shot fired at a target in

the competition for prizes, but the object of training in musketry is to secure the highest possible average proficiency. The first battalion of the 22nd Foot enjoys at present the distinction of being the best shooting regiment in the whole army; but it is not in the least degree probable that in actual service its figure of merit would be what it is in practice at home. Nevertheless, we are warranted in feeling very sure that the rifles of that regiment would do more execution, under equal conditions, than those of any other. Indeed, the same remarks will apply to every branch of military training. Our Field Exercise book is filled with a number of complex evolutions and manœuvres, which it is notorious are never applied in actual service; and even the more useful line and column movements lose much of the wonderful precision which characterises them on the parade ground, when performed actually under fire. Yet no one would, on that account, be so irrational as to seek to do away with our book of Field Exercises and Evolutions. For, although none of the exercises, studied with such care and performed with so much skill, will always be executed with equal accuracy on the field of battle, yet the actual results will always be proportional to the general knowledge and practice of those exercises, previously mastered.

Thus, with regard to musketry, the only way of securing good average efficiency is to aim at peculiar excellence. The practical result will, of course, fall short of the specimen exhibitions, but its value will still be in a direct ratio to the proficiency so acquired. And the nearer our troops are brought, as a body, to the rank of first-class shots by practice at home, the more formidable will they be as a body against an enemy in the field. It may be quite true that in the heat of action a soldier will not think of

many of the little directions he has learnt on parade; but it is equally true that the training he has received will produce its effect, although mechanically, and that his firing will be infinitely more effective than that of a man who has had no training at all.

Moreover, not only are our troops more universally masters of their weapon than at any prior time, but there is not a doubt that they have also derived great indirect benefits from the introduction of the rifle-training system. Rifle shooting and the prizes attached to it have supplied them with a new pursuit and a new motive for exertion. It has diversified the monotony of camp and barrack life, and set up a rival interest against the attractions of the public house.

This musketry training, however, has been by no means limited to the army—it has been extended to our volunteer corps, and with great advantage, even in a purely social point of view. For many reasons sedentary habits had been increasing in the community. The volunteer movement has turned men out of doors, with an object of pursuit that rescues the idle from *ennui*, and gives healthy open-air exercise and relaxation to those whose daily toil is that of the brain.

Our young men have been called out into the fields by the sound of the bugle; and they repair "to the butts," as in the days of the long-bow, when, as good Bishop Latimer used to say, "the might of England stood upon archers," as naturally as they formerly did to other more questionable places of resort.

> "Now all the youth of England are on fire,
> And silken dalliance in the wardrobe lies."

It is mainly to the interest excited by rifle practice that we have to look for the maintenance of this spirit, while it

is the object of musketry instruction and training to make this practice contribute as much as possible to the efficiency of the individual and to the service of the country.

APPENDIX A.

Returns of Musketry Instruction.

The returns for 1861-2, compared with those of the preceding year, show the following improvements:—The number of marksmen has increased more than $2\frac{1}{3}$ per cent., and the number of first-class shots nearly 5 per cent., whilst the third-class shots have *decreased* 6 per cent. The average "figure of merit" has had added to it nearly $5\frac{3}{4}$ points; and the number of corps in which the men classed as marksmen exceed 10 per cent. of the strength has nearly doubled.

The regulation that the number of marksmen in each corps should not exceed 10 per cent. of its strength is a cause of considerable disappointment. Thus, in 1862, of the number of men who had managed, by dint of persevering attention, to obtain the necessary degree of efficiency to qualify them for the badge of marksmen and its reward of 1*d.* per day, ten out of every forty-seven were disappointed of their rewards, because they happened to belong to corps in which the number of marksmen exceeded 10 per cent. of the strength.

APPENDIX B.—Theory of Recoil.

Since the gases generated by the combustion of the powder exert an equal pressure in all directions, that on the breech of the gun at any instant of the explosion will be equal to that acting on the bullet, supposing the windage to be inconsiderable. If, therefore, f represent the increment of velocity of the bullet at any instant, F that of the rifle, w the weight of the bullet, w_1 that of the column of air filling the barrel in front of the bullet, which has to be driven before it with the same velocity, W that of the rifle, v and V the velocities respectively communicated to them at the time when the bullet leaves the rifle, then

$$F = \frac{w + w_1}{W} f,$$

$$\text{And } V = \frac{w + w_1}{W} v,$$

Also, if U be the force of the recoil estimated in foot-pounds *—

$$U = \tfrac{1}{2} \frac{W}{g} V^2.$$

Now the value of v is known to be about 1,250 feet per second, and the weight of the rifle may be taken at 9 lbs. 5 oz.; that of the bullet (with the waxed paper) 537 grains; and that of a column of air ·57 in. in diameter and 36 in. long, 3·6 grains. Therefore, supposing the rifle perfectly free to move, it will have a velocity of recoil communicated to it—

$$V = \frac{540{\cdot}6 \times 1{,}250}{65{,}187} = 10{\cdot}37 \text{ ft. per second;}$$

And the force of recoil in foot-pounds will be—

$$U = \frac{9{\cdot}31 \times 10{\cdot}36}{64{\cdot}38} = 15{\cdot}5.$$

The rifle, held loosely in the hands and striking against the shoulder with this force, will inflict a very severe blow. But if it be held firmly to the shoulder, so that it cannot move without the body move with it, W must be taken, not as the weight of the rifle alone, but as that of the rifle and at least the upper part of the body together, say 100 lbs.; V will then be about ·96 ft. per second and U about 1·45 foot-pounds, an amount quite inconsiderable, and capable of being counteracted by a very trifling muscular effort.

Since— $U = \frac{W}{2g} V^2 = \left(\frac{w + w_1}{2 W g}\right) V^2,$

it is evident that the force of the recoil varies inversely as the weight of the rifle; that of the bullet, and the velocity communicated to it, remaining constant. It is also apparent that the recoil increases rapidly with the weight of the bullet.

In assuming that a velocity equal to that of the bullet is communicated to the entire column of air in the barrel, we have somewhat exaggerated the amount of work done by the explosion of the powder in setting the air in motion, consequently also the amount of the re-

* A foot-pound is the quantity of mechanical power or *work* necessary to raise a weight of one pound through the height of one foot.

RETURN, SHOWING THE GENERAL RESULTS OF MUSKETRY INSTRUCTION FOR THE YEARS 1858-59-60-61 and 62.

DATE.	TOTAL NUMBER OF					PER-CENTAGE OF FIGURE OF MERIT							Number of Men recommended for Rewards	AMOUNT DISTRIBUTED IN MUSKETRY PREMIUMS						Number in excess of Authorised Numbers.	No. of Corps in which Number of Marksmen exceeded 10 per cent. of number who fired.
	Men instructed	Marksmen	Men in 1st Class	Men in 2nd Class	Men in 3rd Class	Marksmen	1st Class	2nd Class	3rd Class	Highest	Lowest	Average		Total Sum			Average for each Man Instructed				
														£	s.	d.	£	s.	d.		
1857–58	42,029	...	9,819	20,620	11,590	...	23·36	49·06	27·58	39·08	14·59	28·31									
1858–59	69,632	3,127	19,566	33,450	16,666	4·50	28·09	47·97	23·94	41·84	15·08	30·37	27·41	5,263	12	1	0	1	6¼	128	17
1859–60	109,321	3,636	16,488	56,623	36,210	3·33	15·08	51·79	33·12	45·95	12·07	31·51	32·00	6,348	19	0	0	1	2	122	6
1860–61	124,588	7,245	25,666	66,852	32,070	5·81	20·60	53·65	25·74	51·66	16·93	33·96	59·67	15,287	8	4	0	2	5½	956	32
1861–62	131,214	10,719	35,521	69,811	25,882	8·17	25·55	53·20	19·72	54·40	26·08	39·69	84·05	15,199	4	2	0	2	3·8	1,827	59

coil. On the other hand, we have neglected the effect of the compression of the air in front, and the friction of the bullet in its passage through the rifle. Of the latter it would be difficult or impossible to take numerical account. Its effect is not considerable so long as the rifle is clean, but increases rapidly when it becomes fouled; causing, as all riflemen are aware, a great addition to the recoil.

If the force acting on the bullet remained constant during its passage through the barrel, the time required to expel it would be $t = \frac{2\,l}{v}$; or, taking $l = 3$ feet, $v = 1{,}250$, $t = \cdot 0048$. But, inasmuch as the force acting on the bullet during the first part of its motion must be much greater than towards the muzzle, the mean velocity must be greater, and the time of motion considerably less, than ·0048 of a second.

If L be the distance through which the rifle recoils during the passage of the bullet through the barrel, then—

$$\frac{L}{l} = \frac{V}{v} = \frac{w}{W};$$

whence, in the case of a rifle free to move, the value of L is—

$$\frac{36 \times 540{\cdot}6}{65{,}187} = \cdot 298 \text{ in.}$$

And, in the case of a rifle held firmly in the grasp, on the former assumption that W = 100 lbs.,

$$L = \frac{540{\cdot}6 \times 36}{700{,}000} = \cdot 028 \text{ in.}$$

This amount is so small that the recoil may be said not to become sensible until the bullet leaves the rifle; and, although owing to the curve of the stock the effect of the recoil is to raise the muzzle, it does not alter the direction of the bullet to any appreciable extent: the bullet leaves the piece too rapidly for that. This has been shown by placing a gun-barrel on a horizontal frame, suspended by a single wire. On the barrel being pointed and fired, the bullet has been found to have no appreciable deviation, although the frame revolves rapidly from the effect of recoil round the suspending wire.

After the bullet has left the rifle, the continued expansion of the gases will cause a further recoil of the rifle, on the principle of the rocket. This, however, will be comparatively small in amount, and, taking place more slowly, may be regarded as unimportant.

APPENDIX C.

Men and Officers Annually Trained.

The following extracts from General Orders recently issued from the Horse Guards by command of the Commander-in-Chief will show the extent to which the army is now annually leavened by the certificated teachers from Hythe and Fleetwood:—

"Classes for Musketry Instruction are formed at the Schools of Musketry, at the under-mentioned dates:—

"1st Term—3rd January.—Special Class for 40 adjutants and 100 serjeants, one-half of whom will be drawn from Militia and Volunteers.

"2nd Term—9th February.—Regular course for 60 officers and 280 men, including 5 officers and 40 serjeants of Militia and Volunteers.

"3rd Term—14th April.—Regular course as above, 5 places being reserved for officers of Militia and Volunteers.

"4th Term—17th June.—Short course for a class of 100 Volunteers.

"5th Term—21st July.—Same as third.

"6th Term—20th September.—Same as fourth.

"When any one of the above dates falls on a Sunday, the class will assemble on the previous day.

"The adjutant of a Volunteer corps or an administrative regiment, when duly qualified by the possession of a certificate from a school of musketry, is to be considered the regular instructor of musketry of the corps or administrative regiment; but it is competent for a commanding officer to employ as additional instructors any officers or non-commissioned officers of the corps or regiment who may be properly qualified for the duty."

An adjutant who does not possess a certificate as officer-instructor of musketry is to attend a course at Hythe or Fleetwood, and, if he fail to obtain a certificate, he is to attend a second course, when, if he again fail, he will not be allowed to retain his appointment.

The regulations as to sergeant-instructors are too lengthy to be transcribed here.

LECTURE I.

[Red Book, First Lesson, p. 21.]

Theoretical Principles—Construction of the Barrel—The Bore—Axis of the Piece—Line of Fire—First Law of Motion—Explanation of Terms—Rest and Motion—Different kinds of Motion.

I. "Theoretical Principles" is a learned phrase, but it has a very simple meaning. The word ".practical" is in everybody's mouth. The first question we ask respecting every suggestion is—"Is it practical?" And we frequently say—"It's all very well in *theory*, but it won't do in *practice*." Now, of all popular errors this is one of the greatest. It is quite impossible for a thing to be really "all very well in theory" and not "do in practice," if words mean anything, and we take the trouble to discover their meaning. The subject is worth a moment's consideration, to enable us to start with a clear understanding. You all know what is meant by *practice*, for, in fact, it is everything that is done —good, bad, and indifferent. Then, what is "theory?" In plain words, it is simply the *reason* of practice. It is a Greek word, formed from one which means, "I behold with attention," "I perceive," "I *experience*."*

II. Therefore, theory is founded on experience. It is necessarily founded on facts. If theory, then, really means the reason of things founded on experience or facts, everything done in accordance with it must be, necessarily, well done. To talk about a "false theory" is simply nonsense with respect to practice; and, if a thing cannot be well done

* Θεωρέω.

according to certain reasons advanced, it simply follows that there is really no theory at all—in other words, no *reasons* based on experience or facts.

Of course, reasons differ in value and soundness, like the common coin of the realm. There are good reasons and bad reasons for everything done; but whatever is well done must, necessarily, be in accordance with good, sound reasons —in other words, *theoretical principles.*

There is, for instance, a good, sound reason for most of the things you are required to do as soldiers—at all events at the present day. Every motion or position of your common drill is founded on the soundest reasons, or theoretical principles; and these reasons can be easily explained on all occasions. We therefore conclude that our "theory" of drill is established; and it succeeds in practice because its reasons or principles are sound.

As an illustration of this, all our manœuvres, field evolutions, in a word all our "tactics," are based on a theory of battle whose object is "to place the right men in the right place at the right time." Suppose we wished to turn an enemy's flank, or advance to the attack of a position defended by artillery, with cavalry threatening a flank. If a position is held by infantry only, and in the presence of cavalry, we should make the advance in column, either single or double, because, if the enemy charged, square could be instantly formed. But, with artillery in front, the advance in column would be simply ruinous. The enemy would rake and rip us to shreds, most conveniently to himself, and sadly to our discomfiture. How then shall we advance, so as to avoid the raking fire of the enemy's artillery, and be prepared for a dash from his cavalry? The theory of tactics at once suggests the appropriate movement —let the battalion advance in direct échellon of companies

from either flank, as the case may require ; and gives us the theoretical principle or reason of the movement in the fact that by such an advance the battalion offers only the same target for the guns as if in line, and, should the cavalry charge, it can at once form company squares, flanking each other to repel it. Moreover, it admits of a ready change of front should a flank be threatened by infantry. In like manner, for turning the enemy's flank this movement is equally valuable ; and the reason is that at a distance it presents the same appearance as an advance in line, and thus may enable the advanced flank to pass beyond the enemy's position, when, by a rapid change of front, the battalion might bear down in line directly upon his flank and turn it. Many instances might be given of the success of the movement in advancing to the attack, especially with armies moving on a grand scale.* So much for the theory of tactics.

The grand theory of war is the result of reasoning upon known facts—experience and its multitudinous suggestions. There must be always a theoretical principle to guide the Chief in planning his campaign and its operations. He may establish himself betwixt the masses of the enemy ; then his reason is to strike them successively as soon as they get at a distance from each other, or on the first favourable occasion, as did the Archduke Charles in 1796, between the two armies of Jourdan and Moreau ; or as did Napoleon with the Allies in 1815. He may fall back, successively occupying each line of defence he has prepared, and finally take position in a post utterly impregnable—as did Wellington in Torres Vedras in 1810, when that wonderful campaign, carried out in accordance with true theoretical principles, saved Portugal, and dealt a blow to the cause of Napoleon from which it never recovered. So much for the theory of

* Col. Macdonald—" Evolutions of a Battalion explained."

war, and the sound reasons for all its successful operations —in a word, its practice.

III. Numerous facts in every-day life need only to be brought to mind to show how we unconsciously avail ourselves of the theoretical principles of science in all its departments. We will take the instance of a smoky chimney. The reason why chimneys smoke is because fresh air is not admitted into the room *so fast as it is consumed by the fire;* in consequence of which, a current of air *passes down the chimney to supply the deficiency*, driving the smoke along with it. In other words, there is not sufficient draught in the room, all being made as air-tight as possible for our own comfort and convenience, without regard to the craving wants of the chimney, which forces us to "theorize" in order to devise a remedy. The *speediest* remedy is to fling open the door or window, to our very great inconvenience. Theory, however, suggests the *best* remedy, which is to carry a small tube from the hearth into the air outside the house. Thus the tube will supply the fire plentifully with air, and you may keep your windows shut, and enjoy your warm fire-side, without the inconvenience of draughts and cold feet.* If we did not know "the reason why" of fire burning or combustion, theory could not have suggested this adequate remedy. A thousand other instances might be given from the common things and occurrences of every-day life and experience. You have a garden, and you dig, manure, and water that garden—that is your "practice," and if any one asks you why you do so, and you proceed to tell him the reason why digging, manuring, and watering the garden will do good and cause it to "bring forth fruit in due season," then you explain the theoretical principles of gardening.

* Brewster—"Guide to Science.

There is really no difference whatever in the meaning of the term, whether we apply it to the common things of every-day life or to science in its learned investigations. In the latter we find certain data, known facts or admitted axioms, and from these we arrive at certain conclusions or inferences. That is to say, a law of action having been made out or guessed at by the consideration of a great collection of facts and careful reasoning respecting them—which process constitutes what is termed induction, the next step is the verification of this law,—that is, the determining whether this law can be considered as established, so that it may constitute a true theory. This tracing of a law from its first glimmerings amidst a series of facts to its formal enunciation, and thence to its final establishment, is one of the most interesting inquiries in which we can engage, since it presents a succession of doubts and confirmations, and every variety of evidence, from the lowest presumption to the highest moral certainty. When, with the utmost precision in time, place, weight, and measure, we have proved the accordance of all the phenomena or facts with the law in question, aided by the refinements of mathematical analysis, then we have established a theory in physics.

IV. Our theoretical principles, then, consist in giving the reasons for all those rules which have to be attended to in practice; and the first thing we have to consider is, the construction of the barrel of the rifle, so far as it affects the flight of the bullet through the air towards its object.

On removing the breech-pin and examining the barrel of our rifle, it will be remarked that it is made considerably thicker at one end than the other. The thicker end is called the *breech*, and the other extremity, towards which the metal gradually tapers, is termed the *muzzle*. The reason for this

form of the barrel is as follows:—The breech has to bear the strain of the lengthened explosion produced by the burning of the gunpowder; and, as this continues until it has overcome the inertia of the projectile, it is necessary in all cases that the greatest strength should be in the breech of the gun. When the bullet is once in motion, the strength of the tube may be rapidly decreased. The strain that one part of it has then to bear, is exerted only whilst the projectile is passing from that part to the muzzle; and this strain becomes of shorter and shorter duration as the projectile approaches its highest velocity at the muzzle of the gun. It is said by Greener that the greatest strain a gun has to bear near the muzzle is that produced by the condensation of the column of air in front of the charge.*

The strength of the barrel at the breech should obviously be proportioned to the pressure or strain brought against it. Now, according to Hutton, one cubic inch of gunpowder is converted by ignition into 250 cubic inches of permanent gases, which are increased in volume eight times at the time of formation by the expansive influence of heat. Assuming these data to be correct, gunpowder confined and ignited in a cavity only large enough to hold it will exert at least a force of 29,500 lbs. on every square inch.†

These conditions, however, do not exist with respect to gunpowder used in a charge, the ball or projectile being displaced before complete ignition of the powder. The experiments of Piobert have rendered probable the assumption that the ordinary maximum pressure of gunpowder on a projectile lies between 2,000 and 3,000 lbs. per square inch.

* "Gunnery."

† Authorities differ, however, as to the amount of this pressure. Robins calculates it at 1,000 atmospheres, or 14,750 lbs.; Col. Boxer and Hyde at 1,530, or 22,567 lbs.; and others at 2,050 atmospheres or 30,237 lbs.

It is evident, however, that to withstand a pressure or strain much less than here stated, a very considerable strength, and consequent thickness of the metal at the breech, must be required. It seems, however, that the necessity for such strength diminishes progressively, so far as the force of the powder is concerned, in proportion to the distance from the breech ; and this admits of the barrel being reduced and made thinner towards the muzzle, as much as is consistent with a due regard to safety, and the employment of the weapon with fixed bayonet, as a pike, with which to resist cavalry, or to make a charge.*

Of course such a formation renders the rifle lighter than it otherwise would be were it of the same thickness throughout. Moreover, by this distribution of the metal, the centre of gravity or balancing point of the rifle is thrown backwards, thus making it easier to poise in the soldier's hand when held horizontally.

In consequence of this construction, the outer surface of the barrel, resembling what mathematicians call the frustum of a cone, lies at an angle with the inside of the barrel, thus:

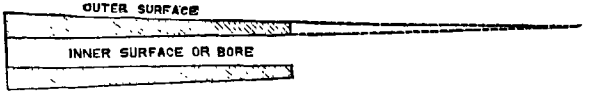

Fig. 1.

* According to certain French experiments it was found that after reducing the thickness of the metal at the breech to less than 1·6 line, that is, a little less than three-twentieths of an inch, a thickness much less than that of the breech of all military rifles, it required the explosion of *two* cartridges to burst it. The French reject their rifles when this thickness gets reduced by use to about five-twentieths of an inch. The thickness of the metal at the breech of the Enfield rifle is ·25 in., or a quarter of an inch. That of the French rifle is over three-tenths of an inch.

thereby giving an "elevation," if we aim along the outside of the barrel itself, equivalent to what is required for aiming at a distance of about 60 yards,—a subject to which we shall revert in the sequel when explaining the nature and use of the *sights* of the rifle.

V. The inside of the barrel is termed the bore, from being bored out with a sharp steel instrument. Its form may be said to be a hollow cylinder.* But as cylinders, in the strict language of geometry, are solid bodies, it may be better, for ordinary purposes, to describe the bore as a tube of the same diameter throughout.

VI. An imaginary line drawn along the centre of the bore represents what is termed the *axis of the piece;* and this line indicates the course which the centre of the bullet takes in the barrel.

VII. This line, prolonged or extended to any length, represents what we call the *line of fire* or direction in which the bullet would move forward, with a uniform velocity, if it were not influenced in its path by any disturbing forces.

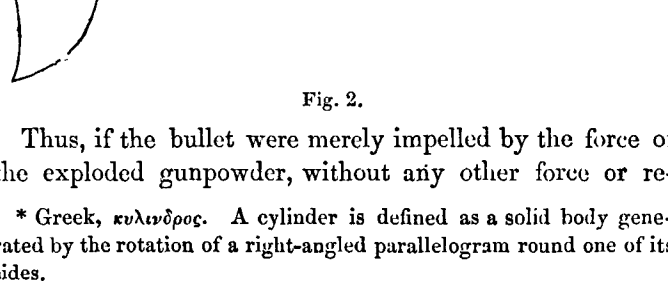

Fig. 2.

Thus, if the bullet were merely impelled by the force of the exploded gunpowder, without any other force or re-

* Greek, κυλινδρος. A cylinder is defined as a solid body generated by the rotation of a right-angled parallelogram round one of its sides.

sistance, it would, by the first law of motion,* proceed onwards in a direct continuation or prolongation of the axis of the piece—along the line of fire B C, with a uniform rate of motion, describing equal spaces in equal times,—so that, if it started with an initial velocity of 1,200 ft. in the first second, then it would retain that rate of motion throughout every subsequent second of time, for ever!

VIII. Motion and rest are relative conditions; and, when a body is in one or the other, it is so because of the forces that have acted or are acting upon it. Matter is, in fact, perfectly passive; and therefore, once set in motion, it would continue in motion for ever, if there were no force tending to bring it to a state of rest.

This seems hard to be understood; and yet, if I remind you of a few well-known facts, you will feel very little difficulty in believing what science teaches on this subject. Our impression respecting the motion of bodies is that there exists in motion some tendency to self-destruction—some disposition, as it were, continually to retard itself, as if from a kind of inertness in matter: because most of the bodies that we see in motion are observed to move more and more slowly, losing their velocity by different degrees until the whole is exhausted, and the body is reduced to a state of rest. But it is clear to us, without any explanation, that in common cases much of the retardation referred to is owing to external causes—mere friction, for instance; and in proportion as we remove this impediment the motion continues longer. A stone rolled along the surface of the ground would continue its onward motion, were it not for the inequalities of its surface, as well as those of the ground on which it moves, presenting impediments which gradually retard its movement, and soon bring it to rest. But if we make the stone

* First law of motion—"A body in motion, not acted on by any force, will move on in a straight line with uniform velocity."

round and smooth, and the ground level, then the motion will be considerably prolonged; a much longer interval will elapse, and a much greater space will be traversed, before it will come to rest. But, polish it as we please or can, asperities or roughnesses more or less considerable will still remain on the surface of the stone and that of the earth; for man can make nothing which does not, when scrutinised by the microscope, present either the edge of a saw or the porous surface of a sponge. But now, let us substitute a ball of highly-polished metal, moving on a highly-finished steel plane or table, accurately levelled, and then the motion will continue for a very long time. Yet, even in this case, for the reason already given, asperities will still remain on the surface of the moving body, causing friction, and bring it to rest. A ball rolled along the ground is speedily stopped; but if it be rolled along a sheet of ice, where there is less friction, the motion will continue for a long time and be slowly diminished. When a coach is suddenly stopped by a violent concussion—as on being upset—are not the passengers and luggage thrown violently forward? By what? By that motion with which they are being carried forward, which once begun must continue, unless stopped by another force or resistance. The passengers and luggage, being bodies unconnected with the coach, are affected by this law. Again, if a passenger in a carriage which moves with considerable speed leap to the ground, he will fall in the direction in which the carriage is moving: for in descending his body will still retain all the progressive motion which it had in common with the carriage. When his feet touch the ground, they and they alone will be suddenly deprived of the progressive motion, which being retained by the remainder of his body, he will fall in the direction of the motion of the carriage.

The sport of coursing presents many striking and instructive examples of the permanence of motion. From the movements of the hare one might suppose that he indeed is an expert mechanical philosopher. The hound which pursues him, being a comparatively heavy body and moving at the same or a greater speed, cannot so suddenly arrest its course, because its motion has a tendency to continue forward in the same straight line. The hare, a comparatively light body, and moreover being prepared for the evolution, first gradually retards its motion so as to diminish the effects of inertia, and, at the moment when the hound, urged to its extreme speed, is in the act of seizing it, dexterously turns at an acute angle to its former course, leaving the hound propelled forward in the direction in which it was previously moving.

Thus, if the line AB represents the direction in which the hound was pursuing the hare, the hare having arrived at the point C, suddenly turns in the direction of CD, while the hound, unprepared for the trick and hurried forward by the force of its motion, is carried on in the direction AB to the point B, while the hare has passed along the line CD to the point D. The distance *now* between the hound and the hare is the line BD, the base of the obtuse angle formed by the lines CB CD, simultaneously moved over by the hound and the hare.

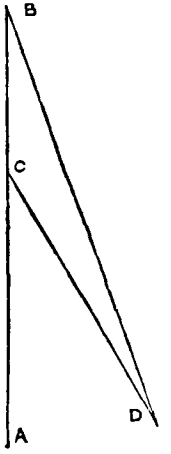

Fig. 3.

Many of the surprising feats performed in gymnastic and equestrian exhibitions are explained by the principle here referred to. As an example, let us take the case in which, while the performer

stands up on the saddle, a table or other elongated object is held before him above the height of the horse, so that the horse may pass under it, while it would obstruct the progress of the rider. In this case the rider leaps over the table, returning to nearly the same point of the saddle which he had left when the horse had passed under. But this feat demands only the muscular exertion of leaping vertically upwards to the height of the table, extremely different from that which might have been expected.

And so in the hunting-field. Not unfrequently a modern Nimrod may be seen riding at a splitting pace with the view of leaping some hedge or wall in front. Up to a certain point both man and horse seem animated by a like resolve; but at the very last moment, when close upon the leap, the horse suddenly and unexpectedly refuses what may appear to him an ugly fence, and pulls up sharp—not so the rider: ignorant of this change of mind on the part of his steed, and being in a rapid state of motion, he continues to move forward, in obedience to the law of motion under consideration, until his nose comes in contact with mother-earth on the other side of the ditch or obstacle.

Numerous other illustrations might be given, but these will suffice to warrant the conclusion that a body has no natural tendency either for a state of rest or a state of motion. It is entirely passive. If it be at rest, it remains at rest: if it be in motion, it continues moving. In the former case, the slightest force which solicits it to move, if not opposed by an equivalent force, is obeyed; in the latter case, that is, when in motion, the slightest obstacle which retards it takes away something from its velocity, and, if such action continues, will finally extinguish the whole motion. Now, the force and the resistance which prevent our bullet from continuing in its flight for ever, and force it to deviate

from the line of fire, are *Gravity* and the *Resistance of the Air.*

We shall reserve for our next lecture the consideration of the action of disturbing forces in determining the actual course pursued by the bullet in its flight. Meanwhile, there are a few terms of which we shall have occasion to make frequent use, and with which it will be expedient at once to become acquainted. We cannot, therefore, do better than append an explanation of them here, by way of conclusion; for—

> "Without its points, lines, definitions due,
> Nought can be shown in science to be true."

In nature bodies have two distinct states—*rest* and *motion.* What is rest? It is the state of a body remaining in the same position relatively to other bodies with which we compare it. Motion is precisely the contrary condition.

Of themselves, bodies cannot pass from a state of rest to a state of motion, nor from a state of motion to a state of rest. This is a property inherent in the very nature of all bodies, and we call it *inertia*, that is to say, the inability of bodies in themselves to move when at rest; or to stop when in motion.

To produce motion an extraneous or outward cause must act on the body; and to produce rest an extraneous cause must act upon it also.

Now these kinds of causes are called *forces.* Thus a force is a cause which produces or tends to produce motion or rest. If forces tend to stop bodies in motion, they are called *retarding* forces; if they tend to increase the motion, they are called *accelerating* forces.

If all the forces which act on a body neutralize or balance each other, the body remains at rest or retains its motion unaltered; in the contrary case, when the forces do not

neutralize each other, the result is an increase or diminution of motion, or a change from a state of rest to a state of motion.

The *space*, the *velocity*, and the *direction* of the motion vary according to the number and nature of the forces which produce it.

The *space* is the distance traversed by the body in a given time.

If the spaces described in equal times are equal, we call the motion *uniform*.

If the spaces described during equal times are *un*equal, the motion is said to be *variable*.

The terms "slow" and "rapid," with respect to motions, are merely relative, since the most rapid motions which we observe about us are slow when compared with the motion of the earth in her path round the sun, and are absolutely inconsiderable when compared with the velocity of light, which takes only eight minutes to reach us from the sun, travelling with the inconceivable velocity of about twelve millions of miles per minute; the whole distance traversed in eight minutes being about ninety-five millions of miles!

If the spaces passed over in equal portions of time become successively larger, the motion is said to be *accelerated*, and if smaller, it is said to be *retarded*. Thus, suppose we have a clock which beats seconds, and observe any body moving in a straight line; if, during the interval of every successive beat the body passes over one foot of space, the motion of this body is said to be *uniform*. It is clear that in sixty beats, or in one minute, it will have passed over sixty feet. But if, having passed over one foot in the 1st second, it passes over more than one foot in the 2nd second, and still more in the 3rd, and so on, then the motion is said to be

accelerated; and if it pass over less than one foot in the 2nd second, and still less in the 3rd, and so on, then the motion is *retarded.*

The *velocity* of a body moving with a uniform motion is the space passed over by it in a given time, as in one second, for instance; hence, when one body is said to have a greater or a less velocity than another, we mean that a greater or a less space is passed over in the same portion of time. Now *one second* is generally taken as the measure or *unit of time* for the purpose of this calculation, and all motion is measured by the space which is or would be passed over in one second. Thus, suppose a man to travel four miles an hour; then his velocity per second will evidently be the number of feet in four miles divided by the number of seconds in the hour. Thus 4 times 5280 (the number of feet in a mile) being divided by 60 times 60 (the number of seconds in an hour) we get the quotient 5·86, or nearly six feet per second—

$$\frac{4 \times 5280}{60 \times 60} = 5{\cdot}86$$

But a motion may vary uniformly—that is to say, it may increase or diminish in a uniform manner: it is then called a *uniformly varied motion.* The force which causes such a motion must be a force that acts constantly on the body, adding every instant a fresh augmentation to the intensity of the motion: in this case we call it a *constant accelerating force;* or, on the other hand, diminishing constantly the intensity of the motion, in which case it is termed a *constant retarding force.*

If a body move with a variable motion, the velocity of the body at any instant is the space which would be passed through by it in one second, if at that instant its motion became uniform. In the case of a uniformly varied motion,

since the force producing it acts continually and with the same intensity during the motion, it is evident that the effect which it produces in one second must be doubled in two seconds, trebled in three, and so on. In other words, its increment, if the motion be accelerated, or its decrement, if it be retarded, will be proportioned to the time.*

* Suppose f to represent the constant increment or decrement of velocity imparted to the body in one second, v the velocity at the commencement of the time noted, t the duration of the motion in seconds, V the velocity at the end of the time t. Thus the increase or diminution of the motion in two seconds will be $2f$, in three $3f$, and in t seconds ft. Therefore $V = v \pm ft$, the sign $\pm$ being positive or negative according as the motion is accelerated or retarded.

If the body were originally at rest, or $v = 0$, $V = ft$, and if it be brought to rest at the termination of the time t, or if $V = 0$, $v = ft$, or $t = \frac{v}{f}$. Hence, the velocity of a body starting from rest with a uniformly accelerated motion is equal to the multiple of the acceleration by the time: and the time required to bring a body to rest, the retardation of which is uniform, is the quotient of its velocity divided by the retardation.

LECTURE II.

[Red Book—Second Lesson, p. 22.]

Laws influencing the flight of the Bullet—Air and its properties—Retardation of the Bullet by the Resistance of the Air—Gravity and the nature of its action—Determination of the Trajectory of a Projectile. Appendices: Practical Method of Constructing the Curve of a Projectile—Consideration of that Curve *in Vacuo*.

I. In the preceding Lecture we described the "line of fire," the prolongation of the "axis of the piece" along which the bullet would necessarily continue to move forwards, unless diverted from its course by some external influences. We now propose to consider the disturbing forces which affect its flight, and necessitate the contrivances of intelligent ingenuity to prevent them from defeating our purpose when we point the rifle towards an object with the intention of hitting it.

These disturbing forces are, gravity and the resistance of the air. It need hardly be said, however, that, in seeking to explain the nature of their action on the bullet, it is foreign to my purpose to enter into a lengthy description of the properties of air, or the still more recondite and obscure question of the nature and cause of gravitation. Yet, so intimately connected is the profession of the soldier with some of the most beautiful and mysterious laws by which the universe is governed, that we cannot well explain the action of air and gravity upon the bullet's flight through space without first referring to some of their properties.

As the air influences the bullet from the first instant it

is set in motion by the gunpowder exploded in the barrel of the rifle, we shall first take its action into consideration.

As soon, then, as the charge of powder is ignited, setting the bullet in motion, the air begins immediately to exert a most violent action upon it, resisting it to the utmost at the very moment when it might be supposed to exult in the conviction that no power on earth can withstand it! It does indeed seem almost ridiculous to say that this opponent of the bullet and the cannon-ball in their fury is actually only the common air we breathe—the air which at times scarcely moves "the light quivering aspen." And yet a little reflection, a moment's consideration of well-known facts, and the explanation which science gives of them, will suffice to relieve us of the doubt and dispel the difficulty. The tempest in its fury knocks down strong walls, uproots tall trees, and, by aid of the waves of old Ocean, which it lashes into madness, destroys the largest ships and sends whole armadas to the bottom. But, what is a tempest? Only air in violent motion—only air impelled with extreme velocity.

On the other hand, that air is a real thing—as material in its nature as a stiff beam or a solid wall—is quite evident by facts familiar to us in daily experience. Open a book so that the central leaves may stand erect; and move the book, in any direction, in a room where the air is in the stillest condition—and what do we observe? The erect leaves are borne down and driven flat upon the others. By what are they borne down? Nothing but the resistance of the air: what else can it be? Again; we get on horseback when no wind is blowing: we start into a gallop, and instantly our hat or cap is—*blown off?* Not at all, there is no wind to *blow* it off. But it is off, notwithstanding: simply because we have literally "knocked our heads" against the wall of air before us.

Perhaps the most familiar illustration, however, is to be found in railway travelling. You walk to a station on a calm summer day, when, to use the common phrase, "there is not a single breath of wind." You walk at the easy rate, of, say, three miles an hour. At this pace the resistance of the atmosphere may well strike you as being "less than nothing"—a nonentity; you enter the carriage, and no sooner has your train attained its full speed, say 30 miles an hour, only 10 times more than your walking pace, than you become at once conscious of what is apparently a strong breeze, coming from the contrary direction to that in which you are moving; and if you put your head out of the window incautiously, away goes your hat by the blowing as it were of a mighty wind—a tempest! But there is no tempest—no wind. It is merely the velocity of the train driving you against the wall of air before it; and, whether a thing be driven upon us or we be driven upon it, matters not the least; the result is the same. The surface of your body has to displace the air as you are carried through it, and the air resists your passage, front to front.

Such being the case, let us put this simple question in "the Rule of Three." If the resistance of the air is so very much greater to your passage, moving at the rate of 30 miles per hour than at three, how much greater would it be if you were propelled through it at the rate of 750 miles per hour, which is about the speed with which a rifle bullet is, at the first instant, hurled into the air? Were such a thing possible even for an instant, the clothes would be torn from your bodies, and the very flesh off your bones.

II. These familiar effects clearly prove that air is really something—a material thing; in fact, as much so, in its essential properties, as any other substance in this world—

wood, beef, or iron; and, unless you were convinced of this, it would be useless to describe what air can do; but remembering its *effects* you will feel little difficulty in admitting the deductions of science as to its properties, and its material influence on the trajectory of projectiles.

III. The air, then, is said to be a colourless fluid, but, in point of fact, its colour is azure or blue, as it appears in what we call the "heavens" or the "sky." There, by reflecting certain rays of light, it becomes visible, although around and near us it is invisible. The entire surface of the globe is encompassed by this aerial envelope, or atmosphere; and, although it does not affect our senses so immediately as the solid and liquid matter by which we are surrounded, yet its agency and existence are everywhere indicated by numerous facts beside those of which we have just been reminded. A cork floats in water because it is lighter than water; and, for the same reason, clouds—which are water in the shape of vapour—float in the atmosphere,* and are driven along by winds, tempests, and hurricanes, which are but air in motion.

It forms everywhere a layer of vast thickness; for in all countries, above the tops of the highest mountains as well as over the plains, we see the clouds carried along by the wind, and between these clouds we behold the deep blue colour of the vast vault of heaven; indicating the height of the atmosphere, just as the colour of the ocean shows the depth of the water. These two phenomena, thus placed in juxtaposition, suggest a similarity in the reason of the colour in the two cases, and its dependence upon the *masses* of fluid. A glass of water taken from the bluest ocean is as colourless as crystal; and so is any portion of the air immediately around and near us. Were it not for the light reflected

* From the Greek words ἀτμός, breath, and σφαῖρα, a globe or sphere.

and refracted by the air and the vapour it contains, the heaven would be dark and colourless; it would appear like a black vault, in which the stars would shine with the same brilliancy by day as they do by night.

The atmosphere is commonly supposed to extend about 40 miles above the surface of the globe; but it has been stated, on the other hand, that the air is sufficiently dense to reflect a sensible light at the height of nearly 200 miles; and Professor Challis recently maintained, on theoretical grounds, that the terrestrial atmosphere was only proved to be somewhere definitely bounded, and not to extend *so far as the Moon.** But, although considerable doubt rests upon the subject of the extreme limits of the atmosphere, there is no question that one half of it is always within $3\frac{1}{2}$ miles, and 99 hundredths within 25 miles, from the surface of the earth.

At all events, for our purpose, it will be sufficient to know that this mighty mass of fluid is expanded over the whole globe, and that its successive layers extend far higher than the highest mountains. It is densest or thickest near the surface, and diminishes in density within sensible gradations until it reaches the limit where its elastic force is no longer able to overcome the influence of terrestrial gravitation. This ocean of air is the great laboratory of animal and vegetable existence, and upon it every living being depends for energy and life.

IV. Air possesses all the principal attributes of *matter*. To prove that the air is "impenetrable" matter, put a piece of cork on the surface of water in a basin; invert a tumbler over the cork so as to enclose it; and force it down to the bottom. The water cannot rise and fill the tumbler simply because the water cannot *penetrate* the air; which is thus

* Brit. Assoc. Oct. 2, 1863.—*Times*, Oct. 3, 1863. Enc. Brit. vol. xviii. p. 56, col. 1, by Prof. Robison.

proved to be impenetrable matter—in other words, to occupy space to the exclusion of any other matter.

If you place your forefinger on the mouth of a syringe and at the same time force down the piston, and then suddenly let it go, you find that it springs up again. What drives it up but the air which you have compressed or pressed down upon your finger? Unless you full-cock the piece, you cannot ram down your wadded rod in cleaning your rifle; and what prevents you but the confined air in the barrel? Lastly, you have all seen or heard of air-guns. These guns drive a deadly bullet with merely a charge of air—the very air we are speaking of. This air is compressed or packed in a strong metallic chamber; in which condition it is of course most uncomfortably anxious to "get out," and the moment you touch the trigger a portion of this compressed air rushes out with tremendous velocity, driving the bullet before it with sufficient force to pass through an inch board at 30 yards' distance; showing that at the same distance it has sufficient penetration to pass through your clothes and your muscles, and put you *hors de combat* just as effectually as though it had been propelled by the gas of gunpowder. Indeed, could we depend upon their mechanism and skilful use at all times, there can be no doubt that air-guns would be very serviceable in ambushes and other stratagems of warfare.* They owe their efficiency to what we call the *elasticity* of air—that property of bodies by which their particles when compressed into a narrower space try to return to their former condition or position the moment the external force is relaxed. In this manner a bow, bent by the tension of the muscles, recovers its previous form when the string is let go, and thus propels the arrow.

* Air-guns were, at one time, actually made use of in the Austrian Service.

V. All matter has *weight*, or, in other words, is acted upon by gravity; and although we talk of "trifles light as air," yet in musketry air is proved to be a "weighty matter." Yes, air can be weighed in a pair of scales just as much as your tea, sugar, or tobacco. Thus, if we take a bottle six cubic inches in area, from which the air has been entirely exhausted by means of an air-pump, we find it weighs exactly two ounces; on allowing the air to enter it, and weighing it again, it weighs two grains more; showing that six cubic inches of air at ordinary temperatures weigh about two grains. Nine pints of air weigh 96½ grains—rather more than a shilling, which weighs 87¼ grains.

On every square inch of the earth's surface the column of air corresponding to it weighs or presses upon it, by gravitation, with the weight of 14·75lbs.; so that multiplying the number of square inches on the surface of the human body, estimated to be about 15 square feet, we find that the pressure of the air on our bodies is actually equal to 31,860lbs! Why does this pressure not crush us to atoms? Simply because it is counterbalanced by the reaction of the air and fluids filling the cavities within and surrounding the body.

It would be quite beside our purpose further to investigate the other various properties of air. At present we have only to deal with its material resistance, and sufficient has been said to convey an adequate idea of the subject. This material resistance results from its consisting of an infinite number of particles, or molecules, as they are called, exceedingly minute, yet, from the immense mass of their totality, capable of exerting prodigious force.

VI. We have now to investigate the manner in which the resistance of the air influences our projectiles.

When a body moves in air with a high velocity, its fore

part strikes against or jostles a certain number of air-molecules—pushes, drives them back, condenses them before it, and forces them to diverge from their previous position. But then, these molecules react upon each other, forming currents on the sides and in the rear of the projectile, whilst other molecules incessantly take their place, to be again pushed and condensed by the projectile as before.

Moreover, it has been found by experiment that the air tends to rush into a vacuum at the surface of the earth, when the mercury in the barometer stands at 30 inches, with a velocity of about 477 yards per second; consequently, when the velocity of the projectile is above that quantity, a vacuum is formed behind it, and a partial vacuum when it approaches that velocity, and, the pressure of the air being thus removed or much diminished on the hinder part, there results an important alteration in the circumstances of its motion.*

The atoms at first compressed as at A (figs. 4 and 5) soon

Fig. 4.

take a direction parallel to the lateral surface of the projectile, as shown at B, and ultimately close in its rear like waves in

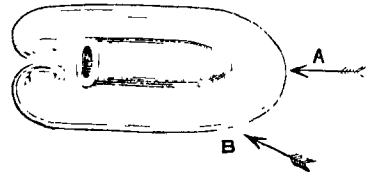

Fig. 5.

* Gay de Vernon, "Art. Milit. et Fortif."

the wake of a ship, thus filling up the temporary vacuum. So that, when a body has attained a certain degree of velocity, the air forms a series of vortices in the rear of the projectile (fig. 4), and these rapidly succeeding each other materially influence the motion of the body.

In this continual action the projectile communicates to each molecule it touches a certain quantity of its motion, more or less, and its velocity is consequently thereby proportionately diminished, just as a billiard ball driven against another communicates motion to the latter, but proves that it has lost velocity in so doing by diminishing in speed, and frequently by stopping altogether.

It is precisely this *loss of velocity* which we are about to investigate; or, referring to its cause, the *resistance of the air*. We define the resistance of the air as the obstacle opposed by the inertia of the molecules of air to the motion of a body, which, in order to overcome this inertia, is obliged to employ and part with a certain portion of its velocity. We may therefore consider this resistance as a real force—a very powerful *retarding* force—whose intensity is represented by the *quantity of velocity* which the projectile parts with to the molecules of air, whose mode of action, according to the various circumstances which accompany the projectile's motion, we have now to study.

VII. Nothing very positive or exact can be stated as to the laws which govern the resistance of the air;* but it is quite sufficient for our purpose to know that air is matter;

* It seems, however, to be generally admitted that the resistance of the air is proportional,

1. To the density of that fluid.
2. To the anterior surface of the projectile.
3. To the square of the velocity of the projectile.

It must be understood that by anterior surface of the projectile we mean that section of it which is perpendicular to the direction of

and as nothing possessing the properties of matter can be displaced or moved from its state of rest without the application of force, as two bodies cannot occupy one and the same space at one and the same time, and as air occupies every part of the bore above the charge and bullet, so that the instant the bullet is set in motion it has to displace the air in front of it,—it is evident that to do this it must employ a certain amount of force. But force used is force expended or lost. You could not walk a distance of 40 miles, and retain at the end of your journey the same amount of strength with which you started. Your strength would gradually expend itself on the road—in the contraction and expansion of your muscles and the tension of your nerves, in overcoming the resistance of friction on the road, the resistance of the air, the resistance of gravitation. And so it is with the bullet. It has, in like manner, to yield up a certain amount of its strength or velocity (for in this case the one depends on and implies the other), so that the force with which it first started becomes gradually exhausted, and its motion becomes slower and slower.

VIII. Moreover, the air's resistance is reactionary in its nature, that is to say, being highly elastic, as previously shown, it reacts on the bullet just in proportion to the blow which the bullet impresses. So that, if the velocity of projection is doubled, the air's resistance is more than doubled; in fact it is quadrupled, for that resistance is as the square of the velocity, or nearly so.*

It is necessary to realise the enormous resistance which

its motion,—for this section is the base of the cylinder of air containing all the molecules which will be met by the body, and which, consequently, can alone have any influence on the amount of resistance, more or less, which this fluid will present.

* See above note.

bodies such as the bullet have to encounter from the air when moving at high velocities, to be in a position to understand how the slightest indentation in the bullet's surface, or the least change in its form, will seriously affect the range and direction of its flight.

IX. Thus, then, owing to the medium through which projectiles have to pass, their power of overcoming resistance becomes less and less at each moment of their progress; the force of projection is gradually spent; and their velocity decreases: so that eventually a bullet would come to rest and remain suspended in mid-air, at some indefinite point of the prolongation of the line of fire, were it not subjected to the action of the force of gravitation.

X. The influence of this force of gravitation or gravity on the motion of the projectile, commencing immediately on its leaving the muzzle of the rifle, will now engage our attention.

It is somewhat difficult at first to conceive that any power can divert a cannon-ball or bullet from its course, impelled as it is with such tremendous velocity, without offering visible resistance. Yet we have already seen that the air is endowed with this faculty; and our daily experience makes us familiar with the enormous power of gravitation. The fall of bodies around us, and occasionally of our own, gives sufficient support to the conclusions of science as to the universality of this force and its influence on all things below and above; while astronomy shows us planets, and probably even the starry suns themselves, circling in their everlasting paths in obedience to this tremendous power, which bends their "trajectories" into elliptical, or oval, orbits.

XI. All bodies when left to themselves fall until they touch the earth, or some other body which can sustain

them. This takes place on the surface of the earth and at great heights above and depths below the surface. The motion thus communicated must be the consequence of the action of some force. The natural inertia of matter, or its passive continuance in the state in which it exists, whether of rest or motion, compels us to admit the existence of such a *force;* and to that peculiar force which produces these effects we give the name of gravity or gravitation, which is only the Latin word for "weight," the weight of a body being the result of its gravitation.

The tendency of this force is to cause all bodies to fall towards the earth, in lines always directed towards its centre, thus:—

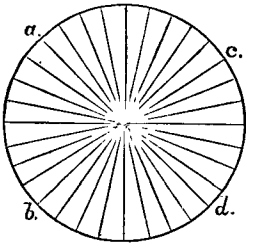

Fig. 6.

But we shall have a most inadequate idea of the importance of this force if we suppose it produces no other effects. It is to gravitation that many other motions are due, to which different names are applied. Thus, for example, the flowing of rivers, the tides of the ocean, the ascent of light bodies in fluids, with many apparently contradictory phenomena, are but indirect effects of that same energy which we call gravitation. The fact of gravitation was noticed as a supposed innate power by the Greeks; and Seneca speaks of the moon attracting the waters of the earth as early as A.D. 38. Subsequently, at different epochs, Galileo, Kepler,

Hook—all great mathematicians—wrote and speculated on the principles of gravitation; but it remained for Newton to discover the great law of this subject. The story is told that Newton, in 1665, then in his twenty-second year and a student of Cambridge, saw an apple fall from a tree. Speculating on the cause, and asking himself the reason why, he conceived that it arose from the earth's attraction; and further inquiry convinced him that our whole planetary system was governed, and all the planets retained in their orbits, by a similar power.

XII. Gravitation, then, acts in lines always directed towards the earth's centre. This direction is called *vertical*. We determine it by means of the *plumb-line*. The direction perpendicular to it is called *horizontal* (fig. 7).

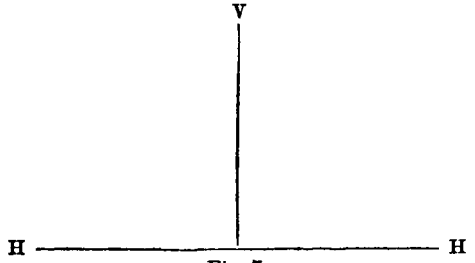

Fig. 7.

By inspecting fig. 6 it will be obvious that the *direction* of gravitation must absolutely vary—however infinitesimally—at the smallest possible distances between any two given points of the earth's surface. At a spot in Caffraria, in South Africa, or China, the direction of gravitation is exactly at right angles with its direction at the spot on which we stand in Great Britain; whilst at our antipodes—or the place exactly opposite to us on the other side of the globe—the direction, although positively on the same line, is opposite to ours, both tending towards the centre of the earth.

In fig. 6, the letter *a* stands roughly for Great Britain, *b* for Caffraria, *c* for China, *d* for our antipodes.

It is generally said that the direction of gravity is perpendicular to the surface of the earth. Now, by this is not meant the actual surface, such as it generally exists with its numerous inequalities, but an *ideal surface*, such as the earth would present were it uniformly curved, like a large tract of still water, or a calm sea.

It is almost superfluous to observe that the common terms "high," "low," "up," and "down," are merely relative to the objects of comparison around and near us. There is nothing of the sort in the grand totality of the universe, wherein we speak, scientifically, merely of distance or motion to or from the centre of the earth.

XIII. But it is not enough for us to know merely the direction of the motion which gravity imparts to bodies. We also require to know whether that motion has a uniform velocity, and, if not, in what manner and to what extent the velocity of the falling body varies ; in point of fact, we want to know how gravity affects the bullet in practice in bringing it to the ground.

To discover this, suppose we take two bullets of the same weight and form, and drop one from a barrack-window 40 feet from the ground, and the other from the window beneath it, say, at a height of 20 feet from the ground, so that both bullets pass the window sill of the lower window at exactly the same instant of time; it will be found that the one which fell from the height of 40 feet will reach the ground *first*, and leave a greater indentation in the soil into which it falls than the other which dropped from a height of only 20 feet. (Fig. 8.)

Again, if a man leap from the height of a chair or table, he will strike the ground without injury ; but, if the same

man leap from a house-top, the chances are that he will be killed by the fall, or at least stand sadly in need of a surgeon.

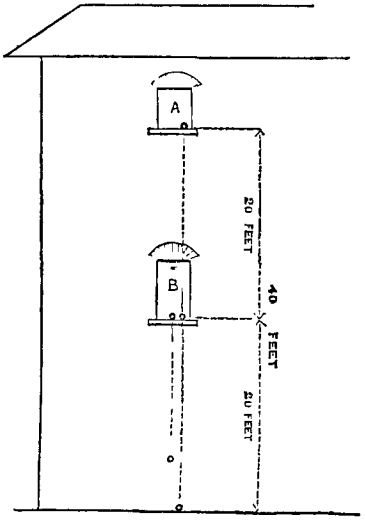

Fig. 8.

A piece of lead, or any other metal, falls very rapidly. The leaf of a tree falls very slowly. The cause of this difference is the *resistance of the air*, which acts much more effectively on the extended surface of the leaf than on a smaller and heavier substance. This is proved by the well-known experiment, in which a guinea and a feather, allowed to fall together from the top of an exhausted receiver, or vessel deprived of air, are found to reach the bottom *at the same instant*.

XIV. We next proceed to inquire what is the law which regulates the velocity with which all bodies fall; or, in other words, what relation subsists between the *space* which a falling body passes through, and the *time* which it employs

in passing through it. This relation is the law of the motion which gravity impresses on matter.

It would appear at first sight that the readiest method of solving this question would be to procure a long glass tube, exhaust the air from it, and, allowing a body to fall from the top, to mark the point which it passes, after one second, two seconds, and so on. But we must observe here, as we may observe in the descent of bodies in the air, that at the commencement of their fall they move slowly, but their velocity augments so rapidly that in a few seconds it is impossible to note, with any approach to accuracy, the point which the body passes at a given instant. A fall so accelerated precludes all direct observation; and recourse must be had to indirect methods—for instance, to Atwood's machine.

The velocity produced by the undiminished force of gravity being much too great to be conveniently subjected to experimental examination, it occurred to Atwood that all the phenomena of falling bodies might be experimentally exhibited and accurately observed if a force of the same kind as gravity, but of much less intensity, were used; so that the motion would still be governed by the same law of gravity, whilst the intensity of the agent being diminished, and consequently the quantity of motion, the velocity might, even after several seconds, not have become too rapid to admit of accurate measurement.

With this view Atwood suspended two equal weights, one at each end of a string, passing over a wheel, turning very easily on its axis. The equal weights are represented at A and B, and the wheel at C. These weights balance each other perfectly, and no motion can take place. To one of the weights, as to B, a slight addition was made; this was generally done by placing a small bar upon B: the bar is

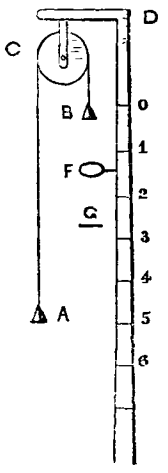

Fig. 9.
ATWOOD'S MACHINE.

shown at G, and is too long to pass the ring F. This ring can be attached to any part of the graduated scale represented on DE. Suppose that B is exactly opposite the zero of the scale, and that the additional bar is laid upon it. The loaded weight will begin to descend, drawing up the unloaded weight A. The descent of the loaded weight is a motion exactly of the same kind as that of a heavy body falling freely; hence the laws of its motion will be the same. The absolute *amount* of velocity will be very different in the two cases, but the mode of its increase will be the same, and this is what we wish to discover.

XV. It is difficult to establish a law by direct experiment, since errors of observation can never be altogether prevented; but we can verify an assumed law, and this is precisely what is done in treating of gravity.

It is proved by observation that gravity satisfies the defined laws of a *uniformly accelerated motion*. Now, the motion of a body is said to be uniformly accelerated when the velocity added is equal for equal times; that is, when the body receives the same addition of velocity in the 4th or 5th second as it receives on the 1st, 2nd, or 3rd, and so on.

When this is the case, it is evident that the velocity acquired by the body must be directly proportionate to the time that the motion has continued. Also, since the velocity is increasing uniformly by arithmetical progression, the mean or average velocity during any given time from the commencement of the motion must be just half of that which is acquired at the conclusion of the same time.

Moreover, since the distance traversed in a given time must be the multiple of the time—that is, the number of seconds—by the average velocity—or the average distance traversed in each second—it is evident that the distance must be proportionate to the square of the time.*

We have therefore the following laws of uniformly accelerated motion:—1. The velocity generated in any time by a uniformly accelerating force is proportional to the *time*. 2. The space described from the beginning of the motion is as the *square* of the time. 3. The space described by a body uniformly accelerated from rest is *half the space* which would be described in the same time with the final velocity; or, in other words, the velocity generated in one second will in the next second, without further increase, carry the body over double the space described in the first, and so on.

Let us now see whether the result obtained by Atwood's machine accords with these laws. For this purpose, let the body B, being loaded, begin to descend from opposite the zero division of the scale, and let it pass by the first division in one second. Then, according to the law that the space is proportional to the square of the time, it ought after two seconds to be opposite division 4; after three seconds to be opposite division 9, and so on; and the experiments made with this machine show that this is the case.

We will now examine what will take place when the additional weight G acts only *for a short time*. Let the ring F be placed at division 1 of the scale: then the weight G will be taken off at the end of the first second, and B will

* These relations are much clearer when stated algebraically. We have already seen (note, p. 45) that if v be the velocity, f the acceleration, t the time, $v = ft$. The mean or average velocity is, therefore, $v_1 = \frac{ft}{2}$, and, if s be the space or distance traversed, $s = v\,t = \frac{ft^2}{2}$.

continue to descend with its *acquired* velocity. According to law 3, it ought to pass by two divisions in the next and every subsequent second, and this is found to be the case; after two seconds it will be opposite division 3, after three seconds opposite 5, and so on.

Similar results may be obtained by making bodies descend inclined planes of different heights and lengths. It was assumed by Galileo, and may be shown to be true, in the descent of bodies on inclined planes, that "the velocity acquired on all planes whose perpendicular heights are equal is the same, and is equal to the velocity which would be acquired by a body falling perpendicularly through an equal height.

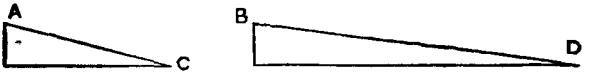

Fig. 10.

The perpendicular heights of the two inclined planes AC and BD being equal, the velocity acquired in descending them will be equal to the velocity acquired by a body falling freely down the same vertical height.

XVI. Hence it appears that gravity acts as a uniformly *accelerating* force, causing all unsupported bodies to fall towards the earth's centre, the rate of the fall being proportional to the time the bodies have been exposed to its influence. The exact rate of this acceleration will therefore be as follows:—Supposing 16 feet to be passed through in the 1st second of time, 48 feet will be traversed in the 2nd, 80 feet in the 3rd, 112 in the 4th, and so on, increasing progressively every succeeding second of time, according to the corresponding odd numbers 3, 5, 7, &c., multiplied by what it was in the 1st second.

XVII.—But it must be observed that nothing has yet been determined respecting the *intensity* of this force of gravity; and this now demands our attention. The experiments

with Atwood's machine show the *rate* by which a given velocity increases, but not the *amount* or intensity of that velocity. This must evidently be determined by observing the free motion of a falling body, when all *retarding* causes —as the resistance of the air—are removed or allowed for. The observations which have led to the most exact conclusions on this point are those made on the time of oscillation of pendulums of various lengths, on which it is not necessary for us at present to enlarge. By the latest experiments it appears that a body at the surface of the earth would fall *in a vacuum* through $16\frac{1}{10}$ feet in one second. But the velocity generated in one second would in the next second carry the body over twice the space traversed in the first, and the space described in the first second thus serves to measure the velocity generated by the accelerating force of gravity. The *acceleration* of gravity is therefore $32\frac{1}{5}$ feet (or more exactly, 32·19084 feet).

We have now sufficiently investigated the properties of air and the laws of gravity to enable us to examine their practical application to the determination of the course adopted by the bullet in its flight.

XVIII. Suppose a gun to be placed on the top of a cliff exactly 144 feet above the level of the sea, and fired with its axis perfectly parallel to the horizon. The bullet quits

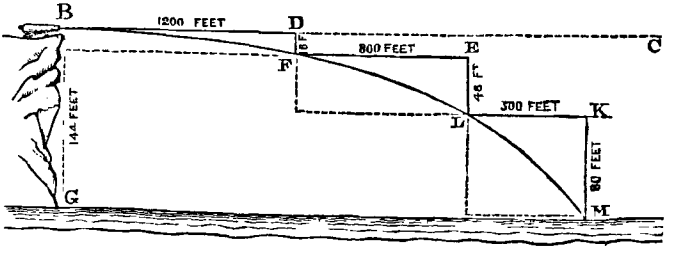

Fig. 11.

the muzzle with a velocity equivalent to 1,200 feet per second. Remember, I merely say it *starts* at that rate; but let us assume that it actually accomplishes that distance, and let the point D in the figure indicate the point which the bullet would thus have reached in the line of fire at the expiration of the first second. We have already ascertained that the force of gravity, never failing in its effect, causes a bullet to fall 16 feet in the first second; hence, not only will the bullet have progressed, but it will have also fallen below the line of fire a distance of 16 feet, which may be represented by DF, drawn perpendicular to the line of fire at D.

Now, the second law of motion is as follows :—" When any force acts upon a body in motion, the change of motion which it produces is in the direction and proportional to the magnitude of the force." In accordance with this law, if a moving body is impressed by two or more forces at the same time, acting in different directions, it will obey neither completely, but adopt a middle or diagonal course, dependent in its nature on the relative intensity of the forces brought into play.

Thus, when our bullet, impelled by the exploding powder in the direction D—the line of fire—finds itself opposed in front by the resistance of the air, and at the same time pulled downwards or attracted by gravity, instead of proceeding to D directly, or, on the other hand, falling vertically in the direction BG, or, finally, stopping short, in consequence of resistance of the air, it has to take an intermediate course, and adopt some such pathway as that indicated by the line BF.

This results from what is called the law of the composition of forces.

The motion of a body may be represented in velocity and direction by a straight line; if then a body have at the same time two several motions, which are separately repre-

sented in magnitude and direction by the two sides of a parallelogram, then the combined or resulting motion of the body will be similarly represented by the diagonal of that parallelogram.

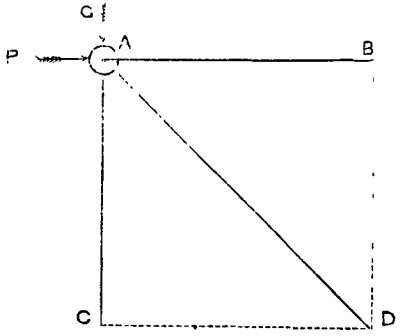

Fig. 12.

Thus, if a body A be acted upon by two forces P and G, communicating motions to it, one in the direction AB, the other in the direction AC, with velocities AB and AC respectively, the result is simply a motion communicated to the body in the direction AD, with a velocity equal to AD. This is called the principle of the *parallelogram of motion*. This is true at whatever angle the motions AB and CD are inclined to each other. Also, if the motions in the direction AB CD be not uniform, if AB AC be taken to represent the total amount of motion in each direction in a given time, the point D will be that which will be reached by the body at the expiration of that time, and it will have arrived at that point by some curved line joining A and D, as in fig. 13.

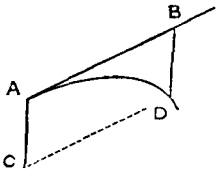

Fig. 13.

If the body have three simultaneous motions, the diagonal or "resultant" of two must first be found, and then the resultants of this and the third.

This law applies exactly to the flight of the ball, the third force being the resistance of the air impeding its progress in front, and would, if worked out with the resultant AD, make the ball A fall nearer to C than D.

In each successive second of time the amount of the horizontal motion is diminishing by the effect of the resistance of the air, while that of the vertical or downward motion is increasing according to the law of accelerated motion already explained. If, then, we add a succession of parallelograms, each commencing at the extremity of the diagonal of the last, and representing by their sides the horizontal and vertical velocities respectively of the bullet at each successive second, their diagonals will show a continual increase of inclination, and will represent approximately the actual path or trajectory of the bullet. But in the actual case these velocities are continually changing, so that the true trajectory is represented by the diagonals of an infinite series of extremely small parallelograms, and, effectively, by a curved line.

The foregoing observations are fully illustrated by fig. 11, to which we shall now revert.

In the 2nd second of its flight, the velocity of the ball having been considerably reduced by the resistance of the air, we may assume that it will not travel more than 800 feet, and will fall by gravity, according to the rule already given, 48 feet, that is, 16×3. The whole vertical distance then traversed will be as the *square of the time*, that is, $16 \times 4 = 64$ feet; and the course of the bullet will be somewhat as indicated by FL.

In the 3rd second of time, assuming that it merely ad-

vances 500 feet, and knowing that it must fall 80 feet, or five times as much as it did in the 1st second (in all 16 × 9, or 144 feet), we conclude that it will move in the direction LM, the resultant or diagonal of the forces acting upon it. The path of the ball between B and M will therefore be represented by the curve BM, which is the trajectory of the ball.

XIX. We have, therefore, clearly established the fact that the ball moves in a curved line, which, in the technical language of musketry, is called the trajectory.*

In tracing the curve it will be observed that on first quitting the muzzle of the gun, and for some time afterwards, the trajectory hardly deviates from the line of fire—the velocity with which the bullet is driven from the gun being at first very great when compared with the effect of the force of gravity; at the same time there can be no doubt that the very instant the bullet leaves the muzzle its path is affected by gravity as well as by the resistance of the air, and consequently we must rigidly maintain that no part of the trajectory is a right line coinciding with the imaginary line of fire.

Gradually, however, the ball yields more and more to the force of gravity, and eventually it moves in a line of rapid curvature to the ground.†

XX. Reverting to the action of gravity, there is a curious fact which seems hard to be understood, and therefore deserves a moment's consideration. If at the instant the gun is discharged at B (fig. 11) we drop a ball of the same form as that fired simultaneously over the side of the cliff, both balls will strike the water at exactly the same time, although the one projected from the gun, besides the fall

* From the Latin word "trajectum," thrown over or across.

† Appendix D, p. 72. Method of determining the Trajectory of a Rifle.

of 144 feet, has travelled forward no less a distance than 2,500 feet.

This is, however, a necessary result of the principle of the parallelogram of motions already explained. We have taken the height of the cliff as 144 feet, and we have seen that a body will fall directly through this distance in three seconds ($9 \times 16 = 144$); but the time occupied by the ball in passing from A to M has been also shown to be three seconds, having reached it by the curved path BDLM. For any other height the time occupied in the descent of the ball may be determined in the same manner, and will always be equal to that by a body in falling freely through the same distance.

In fact, gravity acts by *time*, quite irrespective of the force of projection and the distance travelled by the projectile. Consequently, we have but to suppose this force of projection and the motion produced by it taken away, and the time the ball will take to reach the water, reckoned from the highest point of the trajectory, will remain precisely the same.

XXI. The effect of the resistance of the air is of a different nature. It is, as we before said, *reactionary*—tending to stop the ball; and numerous experiments have proved its powerful effect on the *range* of projectiles. It may be readily shown that in a vacuum, or space deprived of air, the greatest range would be obtained by firing with the muzzle elevated at an angle of 45 degrees; whereas it is found that in air the angle of maximum range is lowered to about 28 degrees. Thus it was calculated in France that a ball fired in a vacuum, with the initial velocity of 520 yards—which is that given by their regulation charge—would have, when fired at an angle of 45 degrees in a vacuum, a range of 8,660 yards; whereas fired in air at an angle of 25 degrees, the distance was under 1,100, that is,

eight times less than in a vacuum, and that no greater range could be obtained by increasing the elevation.*

XXII. Thus, the course, path, or trajectory, of a projectile is at once dependent on the laws of gravitation, motion, and the resistance of the atmosphere. Did gravity not act, the projectile, hurled in a given direction, would continue to move in that direction until its motion was destroyed by the continued resistance of the air. But gravity, constantly acting upon it, deflects it from its rectilinear path, which it bends into a curve, whose particular form may be determined, as we have seen, by the simplest theoretical considerations.

The form of the curve for a ball fired in a vacuum is a portion of a parabola,† with its vertex at the highest point which is reached by the projectile.

If a body be projected vertically upwards in a vacuum it

* The general conclusions to be gathered on the subject of the resistance of the air may be stated as follows:—

1. A projectile in the air traces a different trajectory to that which it would have *in vacuo*.

2. This trajectory is an irregular curve divided by the vertical which measures the greatest height of the flight into two unequal and dissimilar parts, the portion nearest the gun presenting an elongated form, and that furthest from it a quicker curve, which rapidly approximates to the vertical direction.

3. The range of this trajectory varies when the angle of fire and the initial velocity are altered, and it depends, at the same time, on the diameter and the density of the projectile.

4. The maximum range is not at 45 degrees, as *in vacuo*, but at an angle varying according to the nature of the arm and the projectile.

5. Beyond a certain point, no appreciable increase of range is obtained by increasing the initial velocity, in consequence of the resistance of the air increasing in a higher ratio than the velocity of the bullet.

† Appendix E, p. 74.

will descend in precisely the same direction, and according to the same laws as in its ascent—for the destruction of the velocity of its upward motion arises from the continued action of gravity; and this force will generate again precisely the same velocity during the descent.

But, if it be projected in any other direction than the vertical, it will describe a curvilinear path, which will be a portion of a parabola. The deviation of the projectile from this theoretical path, owing to the resistance of the air, is small for small velocities; but in rapid motions, as in those of a cannon-ball or rifle-bullet, the deviations are very great. Hence, the theory of gunnery and musketry requires very many considerations to build up a system which may enable us to secure accuracy of fire—the main object of our endeavours and ambition.

APPENDIX D.

Method of determining practically the Construction of the Trajectory of a Musket or Rifle.

Strictly speaking, in order to trace the trajectory, it would be necessary to find the mean vertical deviation of a given number of shots for all points between the muzzle of the rifle and the limit up to which it is wished to trace the mean curve; for it is obvious, that, if we can obtain the position of the mean point of impact of a given number of shots, fired without changing the charge, direction, or elevation, at all points of our range, the curve can then easily be drawn by simply uniting such points in a continuous line. But, to save the time and trouble necessary for such a labour, it is sufficient for all practical purposes if we limit ourselves to finding the mean vertical deviation of a given number of shots fired under the conditions already specified, corresponding to the principal distances likely to be used in

practice, such as 25 yards, 50 yards, 75 yards, 100 yards, 200 yards, 300 yards, &c., and then use them in the following manner :—

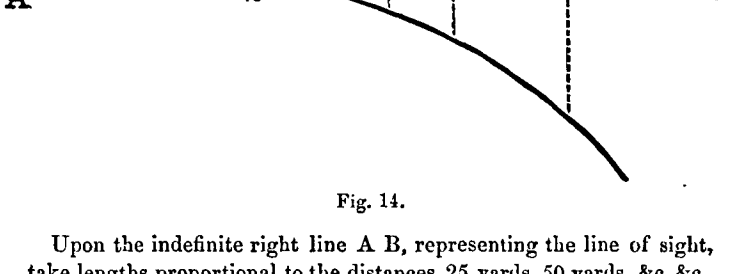

Fig. 14.

Upon the indefinite right line A B, representing the line of sight, take lengths proportional to the distances, 25 yards, 50 yards, &c. &c., and through each point, thus found, draw a perpendicular, upon which measure the vertical distance found for the point of mean impact corresponding to this distance. Join all the points thus found by a curve continuous and regular ; this curve is the same nearly as if we had obtained all the points of mean impact and joined them, or, in other words, it is the mean trajectory of the arm. " This method, simple and expeditious, presents sometimes irregularities ; when, for instance, owing to the difference of height of the points of mean impact, the curve presents inflexions that reason and common sense refuse to admit. In this case it may be rectified by taking into consideration the general form of the curve, and tracing it in such manner as to leave as many points above as below, and to give it a mean direction between all the points. In every case, before making the rectification, we should seek to ascertain the causes of these irregularities, and endeavour to remedy them if possible by new experiments. Such is the method to be followed to determine practically the trajectory of an arm. It was in this manner that the French determined the trajectory of their musket, firing with a charge of 138 grains, and ball 0·62 of an inch. The precautions taken for this important operation, the skill of the marksmen that fired, the care with which they verified by calculation, and corrected by drawing, the data obtained, all induce the belief that the utmost confidence may be given to the result of their labours, and that the trajectory thus determined was as nearly correct as it is possible for it to be."—*Rifles and Rifle Trajectories.* By the Author.

APPENDIX E.

The study of the trajectory in a vacuum will give completeness to our knowledge on the subject, and the following simple diagram will enable us to investigate the matter most satisfactorily :—

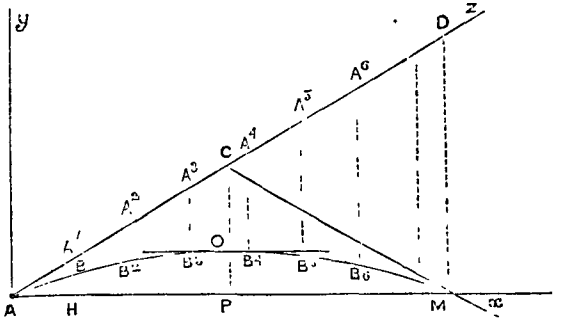

Fig. 15.

From the point A we trace a horizontal line, A x, of indefinite length. We erect A y perpendicular to the direction of this indefinite line A x; and by the oblique line A z we indicate the initial direction of the projectile or the line of fire.

Now, if the bullet were only subject to the original force of projection, it would arrive, after successive seconds of time, at points such as A^1, A^2, A^3, &c., measured on A z at distances equal to the space which would be described in one second with the initial velocity of the bullet, and consequently equal to each other.

But, during its passage from A to A^1—that is to say, during one second—the moving projectile has been subjected to *gravitation*, and has been forced to obey its action. It is consequently drawn downwards to the point B^1, situated in the vertical A^1 H, and below A^1. Of course this fall by gravitation is equal to $16\frac{1}{10}$ feet.

At the end of the 2nd second, instead of being at A^2, it is at B^2—in round numbers 64 feet below A^2—which we obtain from the square of the time, $4 \times 16 = 64$.

After the 3rd second, instead of being at A^3, it will be at B^3—in round numbers 9×16, or 144 feet below A^3. And thus all the points,

B^1, B^2, B^3, &c., trace the course of the trajectory under the influence of gravitation.

The investigation of the trajectory in a vacuum may be carried much further; but sufficient has been said to warrant the following conclusions:—

1. A projectile impelled in a vacuum, and consequently obeying only its original motive force and gravitation, describes a trajectory or path different from the directions of either of those forces.

2. This trajectory is a regular curve, divided into two equal and symmetrical parts by the vertical measuring the altitude or height of the shot at its greatest elevation, as shown by the letters O P in the figure, where C indicates the position it would have without the influence of gravitation.

The following mathematical investigation of the curve of the trajectory *in vacuo* will complete our notice of this subject:—

Let v be the initial velocity of projection, a the angle of elevation. Then the vertical and horizontal elements of the original motion are $v \sin a$ and $v \cos a$; also, the amounts of motion in a vertical and horizontal direction during the time t will be $vt \sin a - \frac{1}{2} g t^2$, and $vt \cos a$; where g is the acceleration of gravity, or 32·19 ft.

Let $vt \cos a = x_1$, and $vt \sin a - \frac{1}{2} g t^2 = y_1$.

Then x_1 and y_1 are the co-ordinates of the position of the projectile at the end of the time t.

$$\therefore vt \sin a = x_1 \tan a \text{; and } t^2 = \frac{{x_1}^2}{v^2 \cos^2 a}$$

$$\therefore y_1 = x_1 \tan a - \frac{g {x_1}^2}{2 v^2 \cos^2 a} \qquad \text{(A)}$$

Which is the equation to the trajectory referred to horizontal and vertical co-ordinates passing through the point of projection.

Let T be the value of t, which will make the vertical motion = 0, or $v \sin a = g\mathrm{T}$. Therefore $\mathrm{T} = \frac{v \sin a}{g}$ is known, and the value of y_1 corresponding to T is $v\mathrm{T} \sin a - \frac{1}{2} g \mathrm{T}^2 = \frac{1}{2} v\mathrm{T} \sin a = \frac{v^2 \sin^2 a}{2g}$ and the corresponding value of x_1 is $v\mathrm{T} \cos a = \frac{v^2 \sin a \cos a}{g}$.

Let

$$y_1 = \frac{v^2 \sin^2 a}{2g} - x$$

$$x_1 = y + \frac{v^2 \sin a \cos a}{g}$$

substituting these values for x_1 and y_1 in equation (A); and reducing we have

$$y^2 = \frac{2v^2\cos^2\alpha}{g}x \qquad \text{(B)}$$

which is the equation to the trajectory referred to vertical and horizontal axes passing through the highest point reached by the projectile.

This is the equation to a parabola whose axis is vertical, and its vertex situated at the highest point, and whose *latus rectum* $= \frac{2v^2\cos^2\alpha}{g}$.

The value of y_1 corresponding to T was found to be $\frac{v^2\sin^2\alpha}{2g}$, showing that the vertical range increases constantly for all values of α from 0 to 90°.

The horizontal range is double the value of x_1 corresponding to the highest point reached, or $\frac{2v^2\sin\alpha\cos\alpha}{g} = \frac{v^2\sin 2\alpha}{g}$. The maximum value of this will be given when $\alpha = 45°$ and is $= \frac{v^2}{2g}$.

If β be the inclination of a plane passing through the point of projection, then the co-ordinates of the second intersection of the trajectory with this plane must satisfy the equations

$$y_1 = x_1\tan\beta,\ y_1 = x_1\tan\alpha - \frac{gx_1^2}{2v^2\cos^2\alpha};$$

$$\therefore x_1 = \frac{2(\tan\alpha - \tan\beta)v^2\cos^2\alpha}{g}$$

$$= \frac{v^2}{g}(\sin 2\alpha - \tan\beta\cos 2\alpha - \tan\beta).$$

And the distance of this point from the point of projection or the range on the plane $= x\sec\beta$

$$= \frac{v^2}{g\cos^2\beta}(\sin 2\alpha\cos\beta - \cos 2\alpha\sin\beta - \sin\beta).$$

$$= \frac{v^2}{g\cos^2\beta}(\sin\overline{2\alpha - \beta} - \sin\beta)$$

The greatest value of which (β being constant) will occur when $2\alpha - \beta = 90°$, or $\alpha = 45° + \frac{\beta}{2}$. In this equation β will be taken as positive or negative according as the inclination of the plane is upwards or downwards from the point of projection.

LECTURE III.

[Third Lesson, Red Book, p. 22.]

Initial Direction to be given to a Bullet to cause it to hit a Mark—"Line of Sight," and Arrangement of Sight for 100 yards, and for different distances—Point-blank.

I. In the preceding Lecture we have examined the physical laws which influence the bullet in its flight, and determined the nature of the curve in which the projectile undoubtedly moves. We shall now proceed to give this knowledge a definite and practical application to our weapon, so that we may be able to derive from it all the important results which we have a right to expect, or, in other words, be able to control and guide the course which the bullet is intended to take when hurled against the enemy.

Indeed, it must ever be borne in mind, that all the theoretical considerations suggested have but one real and practical end or object in view, namely, to enable us to succeed in giving the bullet the utmost accuracy in its flight towards the object aimed at.

II. The first practical conclusion we arrive at from this knowledge of the path of the bullet is, that, "if the axis of the piece is directed upon an object, the bullet will never hit it, but, for the reasons before explained, must pass below it."

It matters not how short the distance, how strong the powder, or how perfect the rifle may be made—the projectile must fall somewhat below the imaginary line of fire. Thus, were the axis even of a *Whitworth* rifle directed on

a point only a few (say six) yards off, and the rifle fired with the largest possible charge of gunpowder, yet, even in traversing that comparatively minute and trifling distance, the bullet would be found to have fallen slightly below the mark. The fall may be infinitesimal—the veriest hair's-breadth—yet gravitation has done its work, and pulled it downwards a little, as far as *time* would allow it; for gravitation is the inexorable tyrant of our bullet, controlling it equally whether shot from the matchlock of the Arab or the most perfect rifle of English manufacture.

III. It has been found by a series of careful experiments that, if the axis of the *Enfield* rifle is directed on a point 100 yards distant, a bullet weighing 530 grains, fired from the rifle with the Government charge of $2\frac{1}{2}$ drs.,* will fall 1 ft. 5 in. in that 100 yards.

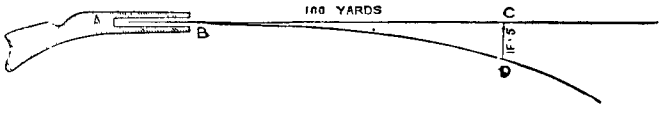

Fig. 16.

Thus, taking BC to represent 100 yards, the bullet will fall a distance (1 ft. 5 in.) CD, below the point C, on which the axis AB was directed.

* Powder and shot are invariably weighed by avoirdupois weight, and for the rifle the custom is to give the quantity in grains. It will be useful to remember the following equivalents:—

1 drachm avoirdupois = $27\frac{11}{32}$ grains
1 oz. (16 drs.) „ = $437\frac{1}{2}$ „
1 lb. (16 oz.) „ = 7,000 „

Hence it appears that the Government charge is little more than 68 grains. The charge of the French rifle is about the same for a much heavier bullet in the case of the Chasseurs, Zouaves, and Turcos' ammunition; and French powder is weaker than ours, although containing less charcoal, it does not foul so much.

Hence it becomes evident that, to hit an object, the line of fire must be directed as much above it as the bullet would fall below it if the line of fire were directed full upon it, and, the trajectory of the bullet conforming to the elevation of the line of fire, the object will of course be struck.

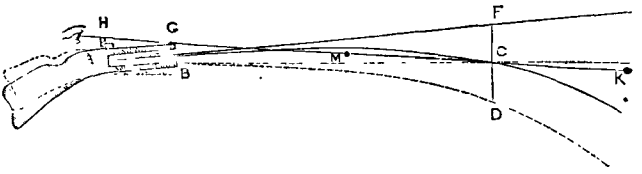

Fig. 17.

Thus, if we wish to strike the object at C, we have only to direct the axis on F—as much above C as D was below it (fig. 17)—and the bullet will hit the mark.

From this we deduce the general principle, sufficiently near the truth for ordinary ranges and elevations, that in order to hit a mark with any gun, at any distance, we must raise the line of fire as much above that mark as the bullet would fall below it, at the given distance, when the axis of the piece is directed upon it.*

* There is a sort of traditional anecdote at Hythe respecting a sergeant, who, after being made acquainted for the first time with this general clue to hitting a mark at any distance, with any given gun, was so haunted by the impressive simplicity of the principle, that he sallied forth to seek an opportunity of putting it in practice. He had not gone far before he found himself at one of those rustic fairs where, amongst other means of teaching the young bucolic idea how to shoot, was a "Rifle Gallery," where bumpkins were attracted by the offer of ever so many nuts and oranges for one penny, provided they hit the bull's-eye of a small target with a pea-rifle, which they scarcely ever managed to do. Full of musketry theory, our friend the sergeant took his first shot direct on the bull's-eye, and, as he anticipated, the shot hit some distance *below* the mark. Measuring with his eye as much *above* it, on the next shot he got a bull's-eye; in the third the

This general axiom comprises the gist of much of the theory of rifle shooting; but its practical application is attended with considerable difficulties, which, however, we overcome in the following manner :—

IV. In order to enable us to point the rifle in any requisite direction, "sights" are fixed on the rifle. These sights consist of small metal projections on the outside of the barrel, of which that next the muzzle, called the "fore-sight," usually terminates in a point, and that nearest the breech with a notch. The line passing through the bottom of the notch of the back-sight and the point of the fore-sight and its prolongation is called the "line of sight."

In taking aim the rifle has to be raised until both these sights are brought into a line between the eye and the point which it is desired to bring into the line of sight. We have seen that in order to strike an object the line of fire must be directed at a point situated at a certain distance above it. If the two sights on the rifle were fixed at equal distances from the axis of the piece, the line of sight would be practically coincident with the line of fire. But if we desire to obtain any accuracy in shooting it is obvious that the eye must be aligned with the mark or object itself. We should otherwise have to guess at the required distance ; for it would be hardly safe, if practicable, to venture up to an enemy's embrasure or loophole, for example, and measure off with a tape the prescribed distance above it. Such an

same, in the fourth the same; in fine, by putting his theory in practice, he hit every time, and, to the astonishment of the beholders, and the confusion and dismay of the owner of the booth, he well nigh cleared the establishment of all its nuts and oranges.

Of course the serjeant, on returning to barracks, became the envy and admiration of his comrades, who speedily scoured the country side in quest of fairs and rifle galleries, in order that they too might try their luck.

arrangement would be inconvenient enough in firing at short distances; but what would it be at "long-range?" At 900 yards, for instance, if the axis of the piece were directed on the object, the bullet would fall about 150 feet below it, if not intercepted by the ground; and how could we measure with the eye in vacant space a height of 150 feet above the object, so as to find the point on which to direct the line of fire, and thus allow for the fall of the bullet? Moreover, it is evident that the muzzle of the piece would always intervene between the eye and the object intended to be struck, and thus render it still more difficult, if not impossible, to direct the line of fire to the required point.

V. We noticed in the first lecture how, by the construction of the barrel, the breech is made thicker than the muzzle. The consequence of this arrangement is, that if we take our aim, or make the line of sight, along the outside of the barrel itself, the axis of the piece, or line of fire, will be elevated at a small angle with this line. This elevation alone will be sufficient to compensate for the drop of the bullet in a distance of 60 yards. The sights of the Enfield rifle are so arranged, that, using the lowest notch of the back-sight, its height, together with the difference in thickness between the breech and muzzle, will give sufficient

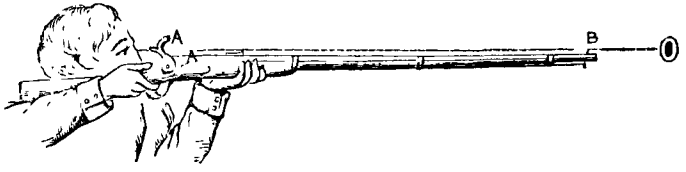

Fig. 18.

elevation for 100 yards. The line AB, fig. 18, shows the manner in which the line of sight is obtained by the align-

ment between the eye, the back-sight and fore-sight, and the centre of the mark or object.*

VI. So far we have been able to arrange matters as to hit a mark at 100 yards, retaining at the same time a distinct view of it. Now let us suppose the mark to be 200 yards off, and that we continue to aim with the same sight as at 100 yards.

If we assign to the point K on the line of sight, fig. 17, a distance of 200 yards, then, according to what was explained in the last lecture, the fall in the second hundred yards will exceed three times its fall in the first, or 4 feet 3 inches. For our present purpose it will be sufficient to take it at this amount.

It would therefore be necessary, with the 100 yards' sight, to aim at a point 4 feet 3 inches above the mark we wished to hit at 200 yards. But this, as already seen, is in practice impossible to the unassisted eye; and as at the distance of 100 yards, so at all other greater distances the line of fire must be directed as much above the object as the bullet passes below that line when laid horizontally at those distances. Now, it is by the ingenious application of "elevating sights," capable of adjustment, that this difficulty is practically surmounted.

VII. The back-sight is made capable of adjustment by means of a flap and sliding bar, and thus becomes available for all ranges from 100 to 900 yards, and, with the latest '62 pattern of Enfield, up to 1,000 yards; so that if the shooter is certain of his distance, and adjusts his "sight" accordingly, he need not trouble himself about "elevation,"

* "Thus straight upon the object aim you take,
And thus the proper elevation make.
Aligning carefully the sights between
Object and eye—the "line of sight is seen."
The Rifle and the Man.

which has been arranged for him in the construction of his rifle.

But, although the back-sight is graduated only to 900 or 1,000 yards, the Enfield rifle is capable of being used with admirable effect beyond these distances for certain purposes —such, for example, as that of a siege, where a large area is presented, and, consequently the utmost accuracy of fire is not essential—for enfilading a redoubt, or hindering a working-party from throwing up a redoubt or field-work. Instances are on record in this country of the Enfield having killed sheep at a distance of 2,000 yards; and in the district of Taranaki, in New Zealand, during the recent war, one was fired with effect from a fixed rest at a distance of 2,400 yards.* After the fall of Sevastopol, amongst other things, Russian officers related that their men, when seated smoking in fancied security beneath their doorways, had frequently been struck down by Enfield bullets, at distances almost fabulous. Its deadly effect at vast distances made it the dread of the Sepoys, who termed it "the gun that kills without making any sound."

VIII. In order to fire effectually at distances beyond those for which the rifle is sighted, the soldier has merely to raise his eye as much above the back-sight as the distance appears to justify, taking care of course that the fore-sight

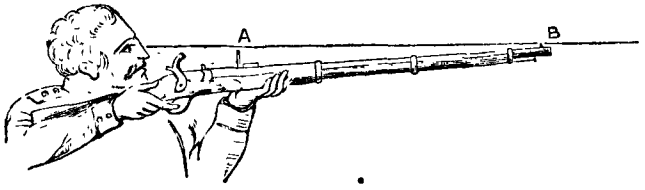

Fig. 19.

* I give this on the authority of Col. Dixon, Superintendent of the Royal Factory of Small Arms, Enfield.

is still kept aligned with the object, as represented in fig. 19, where the "line of sight" AB, though passing some distance above the back-sight, is still aligned with the tip of the fore-sight.

IX. But whilst we enable the soldier to work at long range—to kill at a distance—as it were by mind instead of the material organ, we must not for an instant overlook the importance of directing attention to the short ranges, nay, even the shortest, on which, in many critical conjunctures, his life may be at stake, with a ready and wily enemy before him.

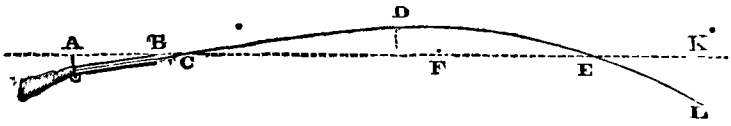

Fig. 20.

At distances under 100 yards, as at E in fig. 20, allowance must be made for the rise of the trajectory over the line of sight, as at D. For this purpose aim must be taken *below* the point intended to be struck. About eight inches will be sufficient at 50 yards, and about four inches at 30 yards.

The knowledge of this requirement would, for example, be invaluable in firing at the loopholes of an enemy's lines at these distances—as in the defence of Lucknow, where the natives pierced loopholes in the houses which surrounded the residency at short distances, and where, owing to the Enfield being over-sighted for distances under 100 yards, it was reported—as stated in Gubbins's account of the siege, p. 221—"that they could not be commanded, nor their fire kept down." Those gallant fellows in the beleaguered garrison had never, evidently, been initiated into this secret of musketry.

Sportsmen often express unbounded surprise at missing what appears to be an absurdly easy shot, owing to the proximity of the game, little thinking that it is the rise in the trajectory, resulting from that very nearness, which causes their shot to whiz harmlessly over the hare or pheasant.

Numerous occasions will occur in battle when the result of a shot at these short ranges must be fatal to you or your enemy. When charged by cavalry it is not likely that you will get the "Present" before the troopers are within comparatively short ranges; and, depend upon it, if you attend to these suggestions, it will be in your power each of you to empty a saddle, or reduce a trooper to his "pins," to scamper back as well as he can to his distant lines; and so you will shake the *morale* of the "thundering legion."

X. If we examine the trajectory of the rifle and its relative position to the line of sight, it appears that, for a very short distance beyond the muzzle, the trajectory is below the line of sight; it cuts it first at the point C, fig. 20. This point of intersection is of no value in the consideration of the firing of arms. Beyond the point C the trajectory gradually rises till it culminates somewhere about D. After culminating it makes a gradual descent till it again cuts the line of sight at the point E.

This point of intersection of the trajectory with the line of sight is of important interest. It constitutes what is termed "the point blank," that is, it is the only point in this range of 100 yards where a small object, such as an apple or oyster-shell, placed on the line of sight, could be struck by the bullet. For, by inspecting the foregoing figure, it will be evident that if we wish to strike an object, F, between the point B and the muzzle of the gun, and aim directly at it, the ball will pass a certain distance

above it, and the same will be the case for all points between B and E.

Again, if we wish to strike an object, K, beyond the second point of intersection, and aim directly at it, the ball will pass below it a certain distance LK, and so in like manner for all points beyond E.

Hence it appears, as before observed, that in order to hit a small object, it is necessary that it should be precisely at the point of second intersection, namely, at B in the present instance, which is the point-blank of the rifle, taking the thickness of the barrel at the breech and the lowest notch of the back-sight as fixing the elevation for the axis of the piece.

This is the correct explanation of point-blank, and the one adopted in the French service and abroad generally; but unfortunately English artillerists have another acceptation of the term, viz., that it means the "first graze" of a bullet fired from the shoulder, the axis of the piece or fire-arm having been kept horizontal. It is very necessary to keep in view the two different interpretations of this term as now applied in the British service in comparing the ranges of French, American, and foreign guns generally. In the remarks which follow it must be understood that we make use of this term "point-blank," and the range corresponding to it, in the sense which we have explained.

XI. It is evident, therefore, that in order to hit objects at different distances, we must multiply the number of *point-blanks;* and it is by means of the elevating sights that this is effected.

Thus, in our rifle, we have a point-blank range for 60 yards in the metal of the gun itself, without the sights; and it is true that, as the elevation begins at the breech, we could obtain the greater elevation necessary for longer distances by increasing the thickness of the metal at the breech; but

such a method would necessitate a different gun for every distance or point-blank, and at 900 or 1,000 yards the metal of the gun would have become so ponderous that it would require more than one man to carry it (fig. 21), such as, I

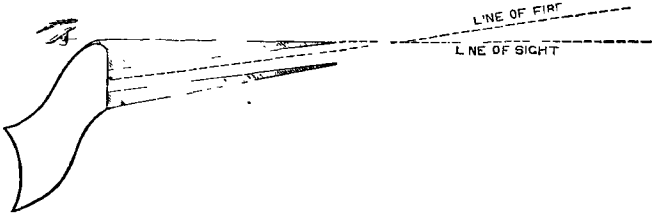

Fig. 21.

have heard Col. Wilford say, might make a very good *winter gun*. But let us see whether it is not possible to improvise, by a cutting-down process, a gun which, by its comparative lightness, may deserve the designation of a "summer gun."

Thus in fig. 22 we have represented the same gun as in fig. 21, with this difference, that every particle of superfluous

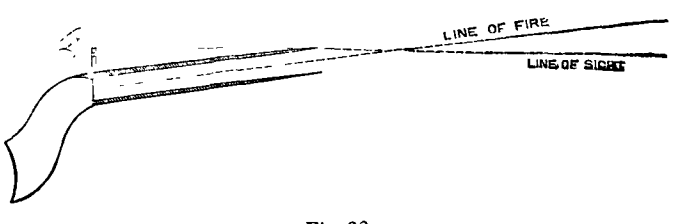

Fig. 22.

metal has been taken away, leaving merely sufficient to secure safety, and retaining a slice of the metal at the breech of the same height as seen in fig. 21. We are thus able to make our new gun fulfil all the conditions of the old gun.

XII. It is thus that elevation could be mechanically con-

trived, and the illustration may be as instructive as it is amusing. The conditions of our rifle being, however, very different, we obtain elevation by depressing the butt and raising the eye above the axis of the piece; and the exact measure of this elevation for each distance has been arranged, as before explained, by means of a graduated sight, capable of adjustment.

Here is a simple method of practically illustrating the principles which regulate the adjustment and position of the sights. It is a model gun, having a small spring in the barrel to project a dart or pointed wooden bullet with sufficient force to penetrate a target at a short distance, and a folding back-sight with sliding bar on the barrel, to afford three lines of sight, viz., one on the surface of the barrel parallel to the axis, one for the distance of about four feet, and one for about eight feet. Put a stopper in the muzzle, with a string tied to the centre, to represent the line of fire, and have another string to show the line of sight. First place the gun at a distance of about four feet from the target, and direct the line of fire upon a bull's-eye marked on the target on the same level as the axis of the gun or muzzle; this being done, remove the muzzle-stopper and fire the gun, when it will be seen that the bullet or dart will strike the target below the mark. Now measure the fall of the bullet, and place a spot upon the target as much above the bull's-eye to be struck as the bullet has fallen below it, and direct the line of fire upon this spot. Again fire the gun, and if this has been done correctly the bull's-eye will be struck. If you look along the sight which is parallel to the axis, you will observe that the muzzle hides the bull's-eye from view; thus, you will see that by directing the line of fire on a spot as much above the object to be hit as the bullet falls below it, you have no

security that the sight is properly directed, nor have you any guide to the elevation, except the previous measurement, which would of course be impracticable when firing with a musket. Now raise the folding sight and the eye, without altering the position of the gun, until the fore-sight is in a line with the bull's-eye; then raise the sliding bar to the height of the eye, and make a mark on the flap to show the elevation due to the distance of four feet, so that now, in order to fire again at this distance, we have only to raise the sliding bar to the mark on the flap, and aim straight at the object. Remove the gun to a distance of about eight feet, and make use of the same sight that has been previously adjusted for four feet, and you will see that the bullet or dart will strike low, thereby showing the necessity of using a higher back-sight for this distance, and the importance of knowing correctly the distance from the mark, in order to regulate the sight accordingly. The stand on which the gun is fixed (*fig.* 23) should have a

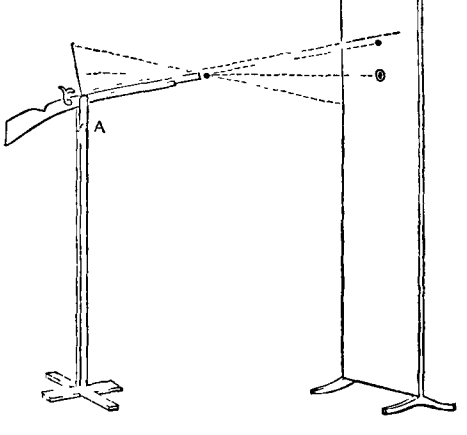

Fig. 23.

hinge at A, to enable the instructor to demonstrate the effect of inclining the sights to one side, which will be treated of in the next Lecture.

Such is the principle of the elevating sights; but, before leaving the subject, some of the conditions which they are expected to fulfil, and the difficulties attendant on that fulfilment in practice, must be mentioned.

XIII. First, as to the sights themselves: whatever may be their form, they should be simple and strong; so arranged as not to embarrass the handling of the arm in the soldier's exercises, on the march, or on any other occasions. Their management should be simple and certain. The soldier should not have to experience the slightest hesitation in the choice of the sight at which the slide should be set. This choice presupposes, of course, a knowledge of distances.

It would be difficult to imagine a back-sight which should more completely fulfil these conditions than that of the Enfield rifle. It combines strength and simplicity in an eminent degree; and, when lying down in its bed of wrought iron, it presents nothing which can be caught up or interfered with, owing to the ingenious steel flanges, which not only effectually protect the elevating sights, but act as supports for the sight up to the distance of 400 yards.

Like the Enfield rifle itself, this sight is the result of collective invention or contrivance. Mr. Westley Richards has the credit of adapting it, so that the flap can be put down on the barrel either from or towards the muzzle—a matter of no small importance in the heat of action and through thick brushwood skirmishing. Mr. Lancaster contributed the protecting flanges; while the Woolwich authorities have the merit of devising the spring which maintains the sight when raised in a perpendicular position.

One of the objections constantly urged against the intro-

duction of the Enfield rifle into the service was that the back-sight was too delicate, and would never stand the rough usage of field service; but the test of actual experience has entirely confuted this opinion, and the wars of the Crimea, India, and China have fully demonstrated, that, in this respect at least, the soldier is worthy of such a weapon being placed in his hands, by the manner in which he has preserved this elevating sight from injury and in good order.

XIV. It must be admitted, however, that the task of proving that he is equally well fitted to be intrusted with this graduated sight, with the object of making use of it when actually engaged against the enemy in the field, is one attended with more difficulty; and it is deliberately asserted that these back-sights should be done away with or "tied down with a wire," because "nineteen-twentieths of the British army," it is said, "are too dull to learn their proper use, and, even after having accomplished that, would lack the calmness and steadiness requisite to develope its advantages in the field"!

In support of such a conclusion—so disparaging to the *morale* of our soldiers—it is triumphantly stated that the French have discarded back-sights, save in their *corps d'élite*. But that is surely begging the question. It is notorious that the mass of the French army—the Line—is sacrificed for those more favoured corps, which are made up of the cream or cullings of the Line regiments, while the latter are not considered worth the time and trouble of instruction in this important branch of a soldier's training. There is no general musketry training in the French army, and in fact, so far as shooting goes, we have nothing to learn from them; and, as to a comparison between the respective armies, the elements of their composition are so

dissimilar that no conclusions of a satisfactory kind can be arrived at.

Doubtless, isolated instances have occurred in which the adjustment of the back-sight has, so to speak, proved a snare and a delusion, and the destructive powers of the rifled musket have been rendered abortive; but these results are attributable not to the use of the back-sight but to its abuse, for in almost every case they can be traced to the fact of the troops employed having been only partially trained to the use of the rifle, to their having been injudiciously manœuvred, or to their having been subjected to some sudden and temporary surprise.

If, whilst in close action, the soldier receives an *order* to use an elevation far beyond what is requisite, the result can no more be attributed to the man or the rifle than the catastrophe of the light-cavalry charge in the Crimea to the men or their horses. It rather points to the necessity of "officers generally making themselves proficient in a knowledge of distances, and becoming thoroughly acquainted with the powers of the rifle."*

At the same time, there is doubtless a tendency on the part of soldiers, in the hurry and excitement of close action, to disregard everything in the shape of aim, and, in their file and volley firing, to fire high. That has always been the case, and doubtless will be always more or less the case; but if anything could obviate this tendency, and overcome the practical difficulty of getting the eye down to the bottom of the notch in the back-sight, it would be by complying with the injunctions of the admirable Circular already quoted. With reference to this very point, His Royal Highness the Field-Marshal Commanding-in-Chief therein promulgates his views for general information, and for the

* *Horse Guards Circular*, 2nd May, 1861.

guidance of officers of all grades in command of troops before an enemy, in order to insure the file and volley firing being in future effectively and rapidly executed.

It is to be understood that, when firing in line or in square at or under 300 yards, the flap of the back-sight is not to be raised at all, but aim is to be taken through the flanges which protect it. This will be found at once to insure sufficient accuracy of direction, and practically to give adequate elevation, as was proved by a company of the Guards while at Hythe in the spring of 1860. Having been marched to the practice-ground, and put through their file and volley firing in the manner above described, the result, as shown by the number of hits, exceeded everything that had been anticipated. For, although the results in shooting at distances beyond 400 yards without using the back-sight are bad, and not to be depended upon, yet at distances under 400 yards they are such as to satisfy the most enthusiastic admirers of "Brown Bess" that the Enfield rifle is a formidable weapon, possessing all the virtues of her predecessor, with none of her vices. In proof of this, I am able to adduce the following interesting facts in the matter of shooting with and without the back-sight:—

	Yards.	Per-Centage.	Average Points.
With the use of the back-sight, 5 rounds, file firing at	200	95·45	6·36
Without . . ditto . . ditto . . 5 ditto . . . ditto .	200	88·90	5·45
With . . . ditto . . ditto . . 5 ditto volleys at .	500	74·00	4·73
Without . . ditto . . ditto . . 5 ditto . ditto . . .	500	16·00	1·00
With . . . ditto . . ditto . . 5 ditto . ditto . . .	700	26·66	1·63
Without . . ditto . . ditto . . 5 ditto . ditto . . .	700	8·00	0·63*

From the foregoing summary, it is evident that at 200 yards the difference is not much in favour of the use of the

* For this summary I am indebted to the kindness of Captain Mackay, D.A. A.G., at Hythe.

back-sight; but at 500 and 700 yards the falling-off is most marked when the back-sight is not used. The fact is, that, provided a man is thoroughly habituated to bring the rifle up to a good position at the shoulder, he may, owing to the comparative flatness of the trajectory at 200 or 300 yards, fire effectively at these distances without taking definite aim, or even bringing down his head to the stock of his rifle.

Nevertheless the Circular referred to does not, on that account, dispense with the other requirements of a rifleman or marksman; for it proceeds to say that—"When firing in the open *at ranges beyond* 300 yards, and at *all distances* when firing behind parapets, or under cover of any sort, the back-sight is to be carefully adjusted, a true alignment taken through the notch of the back-sight on the object aimed at, a correct elevation for the estimated distance being essential for *accurate* shooting."

XV. In conclusion, it is evident that the object of the order in question is to secure effective firing at all the ranges of the rifle in the hands of the taught soldier, as declared in the Circular:—"If the instructions herein detailed are attended to, His Royal Highness is satisfied that the rifle will be found to be a weapon of terrible efficiency in close action, and, when dexterously used, of equal value against bodies of troops, and in silencing artillery at distances up to 900 yards."

LECTURE IV.

[Fourth Lesson, Red Book, p. 25.]

On Elevation—What constitutes Elevation—How it is lost—Shooting up-hill and down-dale—Rifle Ranges.

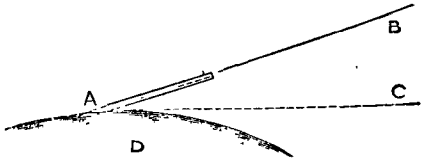

Fig. 24.

I. The purpose of this lecture is to explain what constitutes "elevation" in musketry, or fire-arms in general,—how it is produced, and by what it is lost. First, then, what is elevation? It is the raising of the muzzle of the piece so as to direct the line of fire above the object we wish to hit, thus making allowance for the fall of the bullet by gravity; in other words, raising the back-sight higher above the axis of the piece than the fore-sight, so that, when we align the eye with the distant mark, the butt or breech of the piece becomes depressed, and thus the axis of the piece receives "elevation" or a "rise" above the mark or object.

Such, then, is what we call elevation. Experience taught its necessity to primitive man when he tried to kill a bird or other animal for self-support or in self-defence, or when led by that instinct of "destructiveness" which we have ennobled with the designation of "the chase." The slingers and archers of old—all who hurled the spear, the dart, or the javelin—instinctively, or rather by experience,

gave a "rise," that is to say, "elevation," to their weapons, so as to allow for the fall by gravity. When you fling a stone at any object you "pitch" it high, according to the distance; and, when you were boys and played at ball, you directed your aim in a similar manner.

This elevation is measured by the angle formed by the line of sight (as seen in fig. 25), where CD is the line of sight, AB the line of fire, BOD the elevation or angle of sight.

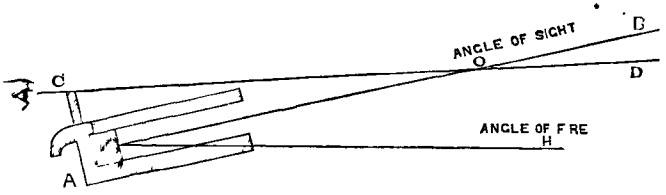

Fig. 25.

The word elevation has been sometimes improperly used for the angle of fire, or the angle formed by the line of fire, and the horizontal shown by BAC, in fig. 24, or BAH in fig. 25.

II. These elementary facts will enable us to form some idea of the mode of determining what height must be given to the back-sight, which is more simple than it appears.

Fig. 26.

Let the above figure represent the gun-barrel with the sights. Suppose any back-sight selected, and some 30 or 40

shots fired always at the same point, so as to discover the fall by gravity, and that we at last succeed in determining the point, which we call the "point of mean impact."*

Now, suppose that in so doing we have sighted with the line CO, and find the point of mean impact has a fall equal to ON, say 1 ft. 5 in. below the point O. We make a black spot on the panel at that point, 1 ft. 5 in. below the point sighted, namely at N, and we return to the spot whence we fired. At that spot we direct the muzzle of the gun exactly as before, and keep it immovably fixed, whilst an assistant adjusts the back-sight, so that the line of sight passing through the notch along the top of the fore-sight may fall exactly on the point N.

This adjustment determines the height of the sight for this distance, since the line of sight CN is precisely the line which must be directed on the point N in order that the bullet may strike that point. We make a mark on the sight, thus fixing the "elevation," and we set down beside it the measured distance, say 100 yards.

If we wish to avoid the difficulties and errors of execution incidental to this second part of the operation, we may assume the two triangles C′CG and OGN to be similar (and they are so without sensible error), and then calculate directly CC′ by means of the usual rule of proportion; for the height of the sight is to the space between the sights (or length of the barrel) as the fall by gravity is to the distance in which it takes place.

Thus, the height of the back-sight CC′ above the fore-sight must be equal to the space between the fore and back-sight CG multiplied by the fall of gravity ON, and divided

* See Appendix for explanation of this term.

by the distance of the object from the muzzle OG. The following is the formula :

$$CC' : CG :: ON : OG ;$$

$$\text{Hence} \qquad CC' = \frac{CG \times ON}{OG}.$$

III. Such are the principles and method of the process by which the backsight is adjusted to give us "elevation." If the backsight is low, the elevation is correspondingly small ; if the backsight is high, the elevation is correspondingly great. Thus, at the distance of 900 yards, the *Enfield* rifle requires a backsight some two inches and a quarter in height, which corresponds to an angle of 3° 6′ ; whereas the *Whitworth* rifle for the same distance has a backsight only one inch and a half in height—equivalent to an angle of 2° 43′—showing a difference in favour of the *Whitworth* of 23′.

Now, of two rifles—all other conditions being equal—that is the better rifle which fires with the least amount of elevation ; for, as will be shown in the sequel, according as the angle of sight is great or small, so will be the height of the trajectory of the bullet ; and it must be borne in mind, in the instance just quoted, that, although at first sight 23′ seems a comparatively trifling difference, yet, in reality, it is very much the reverse,—because the base subtended by a very small angle, such as even the 60th part of a degree, becomes at 900 yards very considerable. An instrument called a clinometer is used for measuring these angles exactly; and, as a knowledge of the comparative elevations required for different weapons at once affords a clue to their intrinsic merit in this respect, we take this opportunity of subjoining the following table (see next page) :—

ANGLE OF ELEVATION IN DIFFERENT FIRE-ARMS.

Distance.	Old Smooth Bore.	Enfield.	Lancaster.	Whitworth.	Westley Richards' Breech-Loader.
Yards.	° ′	° ′	° ′	° ′	° ′
100	0 31	.. ..	0 11	.. ..	0 12
200	0 57	0 22½	0 26	0 21	0 25
300	1 42	0 46	0 49	0 39	0 40
400	2 41	1 3	1 9	0 50	0 55
500	4 13	1 22	1 34	1 8	1 10
600	.. ..	1 43	2 2	1 27	1 27
700	.. ..	2 7	2 32	1 50	1 45
800	.. ..	2 36	3 1	2 6	2 5
900	.. ..	3 6	.. ..	2 43	2 30
1000	.. ..	.. ..	.. ..	.. ..	2 55
1100	.. ..	4 12	.. ..	3 45	3 22
1400	.. ..	6° 20′ to 7°; no hits.	.. ..	5 0	
1800	.. ..	.. ..	.. ..	6 40	

Mr. Henry states that with his new bullet he finds the angle of elevation in his rifle to be at 900 yards only 2° 5′, —the angles at the other distances being in the same ratio.

IV. Thus, from what has been said, increased range is only attainable from a gun with the same powder and bullet by increasing the elevation of its axis with respect to the horizon; and the requisite amount of elevation for any distance, as has been explained, is measured by the graduated scale of the back-sight.

But it must also be borne in mind that the degree to which the back-sight of given height will elevate a gun depends upon its proximity to the fore-sight; in other words, the nearer the back-sight is to the muzzle, the greater the amount of elevation it gives.

The sights, however, must not be placed too near to each other, otherwise the difficulty of making a correct alignment in taking aim will be much increased.

V. As has already been explained, a gun possesses in itself some elevation without back-sights, owing to the

metal being thicker at the breech than at the muzzle. This, however, is neutralized by the height of the foresight, which, in well-constructed pieces, brings the aim, when along the barrel itself, exactly parallel with the axis of the piece, and allows the back-sight to be graduated without reference to the thickness of metal in the breech. The sighting of the rifle thus becomes simplified.

And here we may call attention to this simple mode of ascertaining the elevation at any given distance ; the height of the back-sight, its distance from the muzzle, and the distance being given, the proportion is simply as follows:— As the length of the barrel is to the height of the back-sight, so is the distance of the point to the vertical elevation above the point in question.

By the figure let the back-sight A be an inch aud a half in height ; the length of the tube B 36 inches; the distance EC 900 yards. Then as 36ins. : 1½in. :: 900yds. : 37½yds., which will be exactly the height of CD.

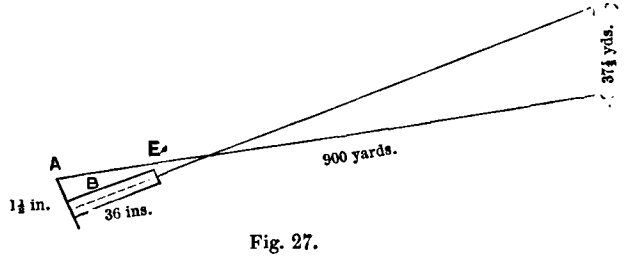

Fig. 27.

As a practical illustration, let us take that of the rifle of Colonel Jacob. With a sight 4½ inches in height, placed 19 inches from the muzzle of the gun, he claimed for his celebrated two-grooved rifle a range of 2,000 yards. Now, let us try to realise what this actually means: by simply working out the "rule of three" sum as follows—

$$19 \text{ inches} : 4\tfrac{1}{2} :: 2000 : x,$$

we find that x, the tangent of the angle, is equal to 474 yards; in other words, with a back-sight so placed, in order to hit an object 2,000 yards off, it was necessary to direct the axis of the piece upwards to a point more than thrice the height of St. Paul's Cathedral!

VI. There is a common saying that "seeing is believing," and there is no better plan of carrying home to a soldier's mind the conviction of the necessity of the backsight, and practically demonstrating to him the relative position of the line of sight and the line of fire, than by removing the breech-pin from the barrel, fixing the barrel on a traversing rest, fastening into the breech a piece of cork or wood having a hole pierced through its exact centre, applying to the muzzle a cap with cross-wires or hairs, and, having adjusted the sight for 900 yards, to make him take a correct aim on a bull's eye marked on the board. Let him now look through the breech, and make a spot at B where the wires cut the vertical line above the mark aimed at A. If the sights have been kept perfectly upright, it will be found that the line of sight falls vertically under the line of fire; and, as the trajectory always conforms to the line of fire, the bullet will, of course, hit vertically below that line in the direction of the line of sight.

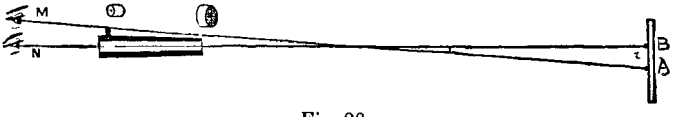

Fig. 28.

VII. Again, in "aiming drill," the soldier is constantly warned against the evils resulting from an inclination of the backsight to the right or the left; so, to prove to him that this advice is sound in practice, a vertical line is drawn on a black board whilst the barrel is on the traversing rest, and a spot is made thereon to aim at. The soldier is then

instructed to aim at the spot with the 900 yards' sight perfectly upright, and afterwards to glance through the barrel, when the axis will be found directed on the vertical line. Then let the same man aim on the same spot with the 900 yards' sight, but inclined to one side. On looking again through the barrel it will be observed that the axis of the piece or line of fire, instead of being directed upon the same vertical line as before, is directed to that side to which the sight is inclined.

Fig. 29.

The foregoing figure shows what is meant by this operation; the line of sight is still directed on the mark, whereas, owing to the backsight having been inclined to the left, the line of fire, instead of being at B, as it was when the sights were upright (see fig. 28), is now directed to C; and, the trajectory conforming to the line of fire, the bullet, instead of striking the mark, will hit at a point D to the right, and also *low*.

That elevation is lost as well as direction may be clearly

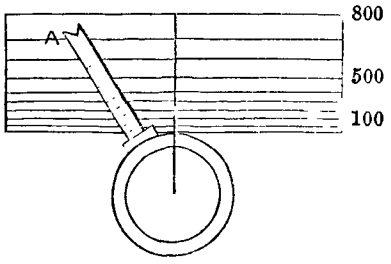

Fig. 31.

shown by placing a card with lines drawn upon it, to represent the proper height of the backsight, at each distance, vertically at the back of the sight, when the exact amount of elevation lost by any degree of inclination of the backsight can at once be seen. Thus, if the sight is inclined, as at A, it at once becomes apparent that 100 yards have been lost in elevation, because the point A is only in line with the elevation for 800 yards.

VIII. Thus it is evident that both direction and elevation are lost by inclining the sights, and this may be shown separately, first, by means of a model-gun with wires affixed to it, fig. 30, to represent the "line of fire," the "line of sight," and "trajectory;" the "trajectory" is made to hinge upon the "line of fire" to show the exact course the bullet will pursue at any degree of inclination of backsight; as also that the "trajectory" always preserves the same relative position below the "line of fire."*

Fig. 30.

As this model is inclined to either side, the bullet's course invariably conforms to the line of fire, irrespective of the line of sight—to which it conforms only when the model is held perfectly upright.

It need hardly be remarked that any error of this kind, detrimental at the short distances, becomes magnified in a greatly increasing ratio as the distance becomes greater,—thus, at 100 yards or so, inclining the sight might merely carry your bullet a few inches to one side or the other—

* The model gun described in Lecture VI. will likewise illustrate the defects herein referred to in a very forcible manner.

instead of getting a bull's-eye, you would merely get a centre; but how immeasurably does any such inclination become increased by distance! For example, if a person, practising at a mark 900 yards distant, tilts the sight half way over to the right or left, as might happen when firing from some cover on the ground, then it may be shown by a simple calculation that, could the bullet be made to fly the requisite distance under such circumstances, it would be projected some 120 feet to the right or left of the intended mark, according as the sights had been inclined to the right or left, and nearly 50 feet below it.*

IX. Of course the sights of rifles are graduated on the supposition that the object to be fired at is on the same level as the firer; but, practically, it is found that little difference in the sighting is required unless the object stands at an elevation, compared to the firing point, of nearly 45° above or below. Whatever position an object may occupy, high on a hill or low in a valley, all that the sights are concerned with is the *distance;* and, this being known, the elevation must be correct at all the usual ranges, all other conditions being equal.

Difficulties have been raised as to up-hill shooting, but they exist in appearance more than in reality. Apart from the optical deception as to the distance—a man or object placed before a high building, tall tree, or hill-side, appearing smaller, and consequently more distant—it is certain that the difference between the true and the horizontal distance of an object is very insignificant. If a target be placed 20 feet above the firer's plane, and the measured horizontal distance be 400 yards, the difference between the horizontal and the direct distance is only *two inches;* but the difference increases with the shortness of the range. At

* Appendix E.

100 yards the difference will be exactly 6 feet; whilst at 200 yards it is only 3 feet; at 300 yards 2 feet, and so on.*

X. The adjustment of the back-sights is correct for all circumstances when they are accurate; and they make the proper allowance for the fall by gravity at every angle within the degree before-mentioned.

If we were to fire a rifle vertically towards the zenith, of course the trajectory would be simply the prolongation of the line of fire.† Gravity would merely act as a retarding force.

Thus, in the figure 32, let AY represent the vertical or perpendicular to the horizon AM, being also the direction of the force of gravity. If the line of fire coincides with the vertical AY, the projectile moves along that line, and gravity, acting in the same line—but in a contrary direction—only diminishes the motive force, and retards the bullet, without influencing its direction.

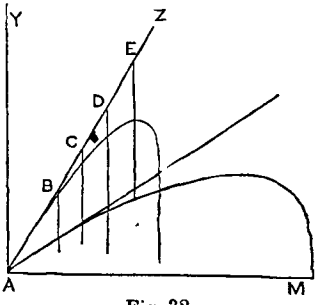

Fig. 32.

* The rule is—*Add to the distance the square of the height, divided by twice the distance, and the sum will be the true distance between the firer and object.* J. B. Huntington, *Volunteer Service Gazette.*

† According to Mr. Huntington, "the Enfield rifle projecting a bullet vertically upwards, the bullet will just reach the altitude of 900 yards before it again returns to the earth." We should like to know how this was ascertained. At all events it is certain that, if a body be projected vertically upwards, it descends in precisely the same direction, and according to the same laws as during its ascent; for the destruction of the velocity of its upward motion arises from the continued action of gravity, and this force will generate again precisely the same velocity during the descent, less the amount lost by the resistance of the air.

But if the line of fire makes the smallest angle with the vertical, as AZ with AY, then the trajectory takes the form indicated in the figure; and, obviously, in order to hit an object situated in the line AZ, the angle of elevation of the rifle must be greater than ZAM, and so on increasing for the other angles.

In the latter case the influence of gravity acts at an angle with the motion of the bullet, producing, by the resultant from the two, the curved line called the trajectory; in the former, the influence of gravity and the force of projection coincide in direction, being simply opposite to each other.

When an object is situated in some oblique direction from the firer, being neither horizontal nor vertical, the bullet is both retarded and deflected from its course—retarded by the resistance of the air, and at the same time, according as the object is higher or lower, retarded or accelerated by gravitation, which also bends it out of its course.

XI. The degree of elevation required will depend upon the time of the bullet's flight, because gravity acts by time. Thus, when the time of the bullet's flight is greater than the time of gravitation down the vertical distance from the point to which the line of fire is directed to the object, it will be necessary to give more elevation to the bullet or it will fall below the object; but, if the time be less, the sight must be lowered. The elevation of a rifle, levelled at an object on the horizon, is the vertical distance intercepted between the object and the line of fire. The time of a bullet travelling along the whole range is measured with sufficient accuracy by the time of a body gravitating along the vertical of the elevation; consequently, when the initial velocity is known, the loss of velocity due to the resistance of the air can be determined separately from the

deflection of the bullet by gravitation, because we have, by means of our present sighting, when duly adjusted by experiment, the measure of both influences combined. The resistance of the air may be practically considered to be the same in any direction—upwards, downwards, or on the level, since its density does not sensibly vary near the surface of the earth within the limits of the elevations in question, and its resistance is, therefore, independent of direction. When the firing is upwards, the speed of the bullet is partially neutralized by its constant tendency to return to the earth ; and its velocity, consequently, undergoes a diminution which must be counted as additional to the retardation due to the resistance of the air.

XII. In firing "down-hill" of course the case is reversed. Here gravity increases the velocity of the bullet, and consequently flattens the trajectory; but of course it always tends to bend it from the object fired at towards the vertical through the point of firing, especially when the rifle is directed at any considerable angle from the vertical.

If we fire from a point A to B, it is obvious that the trajectory will only be the prolongation of the line of fire; but with the angle A from A to C, the trajectory must curve inwards, as A*f*, and so on, as in the figure. Here, however, the velocity of the bullet will be increased by gravity; it will travel quicker ; there will be less time for the curving influence of gravity ; and less elevation will therefore be required, varying, of course, with the angle of direction; but all rifles must, for the above reason, be actually "over-sighted" in firing down-hill, and the firer must use his own judgment accordingly

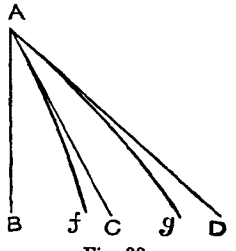

Fig. 33.

as to how much lower he should aim. Doubtless our marines, who may be required to fire from the crosstrees of the masts and other elevated positions, are carefully instructed in this matter. It was a shot of this kind, by a marksman, that ended the career of England's hero, the great Nelson, at Trafalgar.

Of the two conditions of firing, up-hill and down-hill, the latter is decidedly the more advantageous, First, the position is less constrained, indeed, anatomically, it is even more advantageous, than the horizontal, and the vision is more accurate; there must, therefore, be more steadiness in the aim: and, secondly, as we have seen, the force of gravity becomes an aid, rather than an interference.*

With reference to this question of "up and down hill shooting," we subjoin the following description of the rifle range of the 26th Lancashire Volunteers, near Wigan:—

The practice ground is along the slope of a hill, and the target is placed near the bottom, on the bank of the opposite side of the valley. The ground rises moderately up to 500 yards, at which distance the shooting stand is 82 feet higher than the foot of the target (rise of 5 per cent.), thence it is steeper, so that with an average rise of nearly 8 per cent., the shooting stand at 1,000 yards is 236 feet above the level of the foot of the target. From this inequality of the ground, it naturally arises that the distance of 1,000 yards may be measured in two different ways, and with two different results, viz., either along the incline, in the direct line of aim, from the hill downwards to the target, or along the horizontal line underground, the 1,000 yards post to be fixed at the point where the perpendicular raised on the end of that horizontal line, 1,000 yards long, reaches the surface. It stands to reason that the second method would give the longer line, and in this instance it would place the 1,000 yards post at a direct distance of 1,014¾ yards from the target.

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* Appendix F. p. 117.

Longitudinal Section of the Practice Ground of the 26th Lancashire Volunteers.

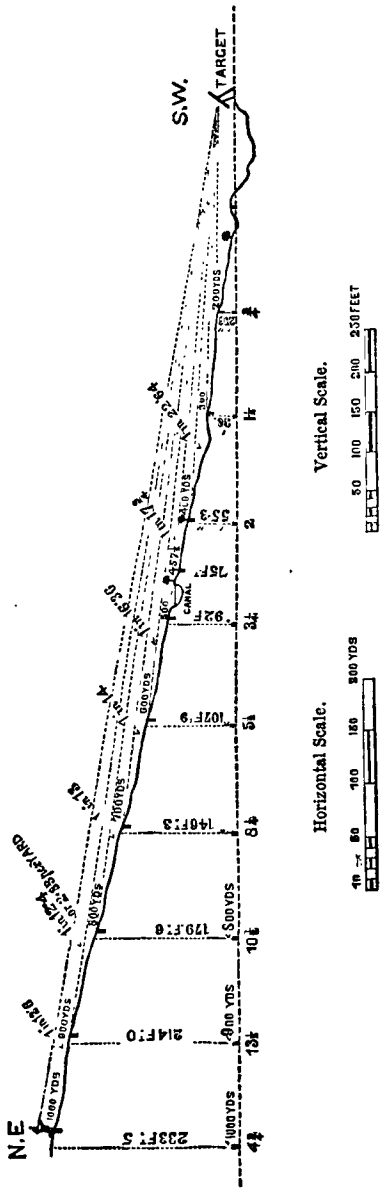


Fig. 34.

The above is from Blanch's "Volunteer Book of Facts," and it is followed by a query whether "the 1,000 yards should be measured horizontally or along the inclined plane in which the bullet has to travel, and what is the law of projectiles bearing upon this question?"

We have endeavoured to answer these questions, amongst others of a similar character, in the foregoing observations. The different distances should obviously be measured "as the crow flies," or "in the air," as the Yankees put it, either by means of triangulation or a stadiometer, such as is used in the service for judging distance; and, having thus obtained the absolute distances in firing, the rifleman must be guided as to the slight allowances to be made for the difference in elevation by the consideration here advanced.

While on this subject of ranges we will add a few remarks as to the considerations which should mainly guide those intrusted with the selection, inspection, or formation of rifle ranges.

These considerations may be said to resolve themselves into three heads:—

1. The range itself.
2. Its safety.
3. Its suitability.

1. The range itself must be considered with regard to the maximum distance for which it is intended to be used, and also as to the number of ranges required for the regiment or company.

In reference to the first point, Captain Coles, in his "Hints on Rifle Ranges," naïvely remarks that,—

"A 300 yards range is better than none; 600 better than 300; 900 better than 600."

With the Enfield rifle, now sighted for 1,000 yards, and

the small-bore match rifle, available for distances up to 1,800 yards, our advice would invariably be to take all you can possibly get as to length of range. Just as our skill in shooting improves, so does the desire or appetite for long-range shooting increase. A man who has once killed a salmon cares less to go back to trout-fishing; and, after once tasting the sweets of bull's-eyes at 1,000 yards, no man cares much about making them at 100.

The number of targets or different ranges must be regulated by the number of men who would probably have to fire at the same time; and, in determining this question, the following data should be borne in mind:—

With iron targets of the regulation pattern, if the markers are good, the fatiguemen well accustomed to their work, and the men well drilled and used to target practice with sections of the average size, a fair allowance for the time required to fire, including checking and washing-out, would be:—

Half a minute	per round	in the	3rd class.
Three quarters of a minute	„	„	2nd class.
And nearly a minute	„	„	1st class.

For instance, a section of 12 men would take—

One hour	to fire 10 rounds (2 distances)	in the	3rd class.
One hour and a half	„	„	„	2nd class.
Two hours	„	„	„	1st class.

At the expiration of which time every thing should be ready for the section to recommence.

Even if the men are firing well at the shorter distances in the 3rd class, it will be necessary to have a clear target ready for the last 2 or 3 rounds at each distance, otherwise there is a difficulty and consequent delay in marking, from the shots being so numerous and close to each other. Again, the number of men proportionately affect the length of time required.

2. However eligible the ground for the proposed range may otherwise be, no advantages will justify its use as a rifle-range unless it can be so used with *safety*.

Under this head Captain Coles says:—"Fire towards the sea, or towards water or marshes at least half a mile broad, or against a hill or rock 50 feet high." No *inland* range can be pronounced absolutely safe; but under certain conditions the probability of accidents becomes so remote that it may be considered as practically nullified.

Some of these conditions may be enumerated as follows:—Ranges should be established by pairs, with an interval of not less than 10 yards between each range, and with a margin for a single pair of at least 40 yards at the sides. Therefore, the minimum breadth of ground for a pair of ranges should be 90 yards.

When two or more pairs of ranges are to be established on the same ground, the targets must be in the same line, a space of 90 yards being allowed between the centre of one pair and that of another, and 40 yards at the sides of the outer ranges, so that the men on each pair of ranges may fire independently.

When the number to be exercised in rifle practice is large, and the breadth of ground available for the purpose is limited, three or four ranges may be established with an interval of 10 yards between each, to be worked or used as a pair, with a margin at the sides of the outer ranges of at least 40 yards.

The width of the ground in rear of the targets, at each side of the outer ranges, should gradually increase from 40 to 80 yards when the ranges are parallel, but when they converge towards the targets this increase of margin may or may not be required, according to the degree to which the ranges are made to converge.

It must be borne in mind that the distances at the targets between ranges in pairs and between pairs of ranges must never be less than 10 yards in the former case, and 80 yards in the latter whether they are laid out parallel to each other or made to converge towards the targets.

The space behind the targets on level ground should be about 1,500 yards. A less distance may however answer if a steep hill rises in rear of the targets. Of course, before steps are taken to procure ground for ranges, it is essential to secure the right to fire over the land behind the targets to the extent required, should it not be desirable to purchase it. Facilities for obtaining this have been provided in the Volunteer Act.

The height of butt against which the targets are to rest may differ according to the nature of the back ground.

A knowledge of the trajectory of the *Enfield* here comes practically into play. For example, this question might arise: If a man at the 500 yards range inadvertently made use of his 900 yards sight, then what height should the target-butt have in order to stop or catch a bullet thus fired? Clearly 50 feet; because we know, when fired with the 900 yards elevation, a bullet culminates at that height at about two-thirds of the range from the firing point.

According to the Regulation,* if the range be on a plain, the butt should be from 45 to 50 feet high if the distance behind the target is less than 1,500 yards. Under ordinary circumstances the height of butt need not be more than 20 feet, and, when firing seaward, a butt of 12 feet in height will be sufficient. On some grounds there are found natural butts for the targets to rest against. To be of use in stopping stray bullets, and thereby ensuring the safety of the public, the hill should be at an angle of at least 45°; if at

* School of Musketry Text Book.

a smaller angle it would, instead of acting as a stop-butt, increase the chance of ricochet, and therefore be unsafe. The length of butt for a pair of ranges should not be less than 45 feet, measured at the top. Platforms of stone or iron, 20 feet by 9 inches, must always be laid down in front of the butts, to rest the targets upon, and to ensure their position at right angles to the line of range, which must be measured and marked every 50 yards from 100 to 900 yards, or to the extent of ground if of a less length than 900 yards.

Before finally "passing" a range it is well to refer to an Ordnance Survey map of the locality, and mark off round the site, at the proposed butt, a rectangular inclosure of 2,500 yards in length by say about 200 yards in width, as in fig. 35, where A represents the furthest point of the range, B the target-butt, and the dotted line AD the line of fire.

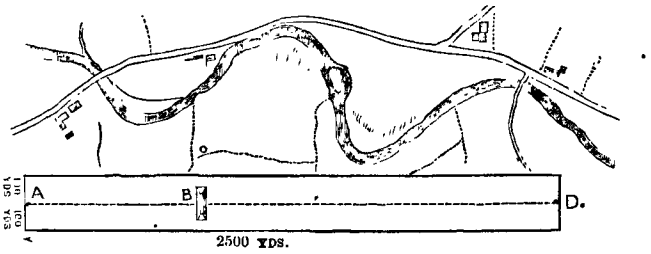


Fig. 35.

It will thus be seen at a glance what houses, roads, paths, trees, and enclosures the proposed range may impinge on or embrace; of course the larger the scale of map for this purpose the better.

If necessary, provision should be made that, in addition to the ordinary Regulation danger-signals, one man or more, according to the nature of the ground, should be

posted at least 100 yards to one side of the line of fire, so as to be able to signal to the party at the firing point the fact of danger in the approach of people, cattle, &c. coming within the prescribed limits, as indicated by the boundary line on the map. Hence, in selecting ground for ranges care must be taken that the space behind the targets should be thoroughly commanded from certain points sufficiently clear of the line of fire to ensure the safety of the look-out men, so that the fire may be easily stopped when necessary; and it is evident that a range down hill is preferable, being more easily commanded than one up hill (fig. 34).

The position and safety of the marker's screen are matters of the utmost importance. Accidents are impossible with the French screens, which are rectangular excavations, whose top is on a level with the ground in front of the target, the butt being a mound of the soil, leaving a trench of considerable extent between itself and the screen or pit of the marker. But, indeed, as the French targets are merely iron frames, daily pasted over and papered, the bullets go through and bury themselves in the mound, whilst the chance of hitting the iron frame is but small, and no amount of rebound in the splinters of the bullets can possibly reach the marker.

Efficiency and safety are the objects to be followed in all these arrangements, the prevention of accidents being of paramount importance, as they entail not only useless suffering, but vast obloquy in these days of universal publicity. In former times, when our forefathers had to prepare for Cressy, Agincourt, and Poictiers, in their practice at the butts, with their bows and arrows, it was the law of the land, if a man or beast got wounded by the practice, no responsibility was incurred by those practising for the service of their country. It was set down as an accident, and

nothing more was heard of it. At the present day there would be a trial, possibly, for manslaughter, and in any case a large amount of damages would be demanded.

3. Lastly, there remains the consideration of the position of the range with reference to the *convenience* of those who have the use of it. In the case of a range to be used by troops of the Line, or by Volunteers who have a wholesome regard for their personal comfort, as well as their success in shooting, this is a matter of no slight importance, for it includes not only the suitability of the range as to its distance from quarters, but also its position as to sunlight, wind, &c.

With regard to the distance, a short march in cold weather does good by quickening the circulation of the blood and preventing that numbness of the fingers so fatal to good shooting. In warm weather, however, it is just the reverse, for the less the muscles are relaxed by previous exercise before firing the better.

With regard to sunlight, the hour of the day when the range is most likely to be used must be considered ; but, as a rule, in the northern hemisphere we should fire towards the north, and in the southern hemisphere towards the south.

In our little island the wind may be said to blow all round the compass ; but where it has a prevalent quarter we should arrange, if possible, to have it in our right rear. A wind from the right is preferable to one from the left, because the natural *deriration* or drift of the bullet is from left to right ; and it will be counteracted thereby, as will also be the firer's pull, which causes the bullet to deviate in the same direction, namely, from left to right; but we reserve the further consideration of sun and wind, and their effects, for our 7th Lecture.

APPENDIX F.

The following Table of Elevations for up and down firing, drawn up by Mr. Huntington, and communicated by him to the Volunteer Service Gazette, is, at least, interesting.

TABLE of ELEVATIONS of the ENFIELD RIFLE in SECONDS of a DEGREE.

Angle of object in degrees.	100 YARDS.		200 YARDS.		300 YARDS.	
	Height of object in yards.	Elevation of rifle in seconds.	Height of object in yards.	Elevation of rifle in seconds.	Height of object in yards.	Elevation of rifle in seconds.
UP.						
45°	70·71	529	140·42	1215	212·13	2128
30°	50·00	633	100·00	1462	150·00	2432
15	25·88	681	51·76	1559*	77·64	2631*
0	**0·00**	**688**	**0·00**	**1547**	**0·00**	**2578**
DOWN.						
15	25·88	646	51·76	1436	77·64	2340
30°	50·00	558	100·00	1231	150·00	2013
45°	70·71	449	140·42	984	212·13	1577

Angle of object in degrees.	400 YARDS.		500 YARDS.		600 YARDS.	
	Height of object in yards.	Elevation of rifle in seconds.	Height of object in yards.	Elevation of rifle in seconds.	Height of object in yards.	Elevation of rifle in seconds.
UP.						
45°	282·84	3230	353·55	4519	424·26	6642
30°	200·00	3744	250·00	5191*	300·00	6881*
15°	103·52	3914*	129·40	5389*	155·28	7056*
0	**0·00**	**3781**	**0·00**	**5157**	**0·00**	**6704**
DOWN.						
15°	103·52	3437	129·40	4838	155·28	5958
30	200·00	2902	250·00	3874	300·00	5037
45	282·84	2259	353·55	2992	424·26	3797

"The numbers marked with an asterisk [*] show where the sighting should be raised, which is certainly the exception, and not the rule. It begins to be conspicuous first at 200 yards and increases as the ranges get longer, but only for up-hill shooting. There are two causes operating to produce the singular effect that at 15° or 30° elevation the sighting must be higher, but at 45 lower, as exhibited

in the table. At the higher elevation, while the force of gravitation acts vertically, the angle between the lines of direction and projection is, as it were, more pinched in than at the lower elevations;—for instance, at 400 yards the bullet falls vertically 27 feet at an angle of 45° elevation of object, but only 23·71 feet at 15° elevation; therefore, the apparent angle, though subtended by a lesser base, is relatively less acute when firing upwards; but, on the contrary, firing downwards, the bullet falls vertically only 20·60 feet at an angle of 45°, and 18·39 feet at 15° depression, so that the angle of the sighting becomes more acute for the higher elevation, as may be easily proved by calculating it according to the well-known properties of triangles."

This table of angles in seconds of a degree of the elevation of the rifle is very useful when making a comparison between two different specimens of rifles, but it is not sufficiently clear to the comprehension of an ordinary marksman, who knows more about yards of range on his back-sight than seconds of elevation. The same writer has, therefore, framed the following table in exact correspondence with the former, substituting yards for seconds, the calculations being based on the known graduations already existing on the back-sight, representing every hundred yards. "Supposing therefore, that the space between each mark can be divided into 100 equal parts, each part will very nearly represent a yard of range; hence it is very easy to set the slide to any given intermediate distance nearly enough for practical purposes. For example, if an object be directly measured 300 yards distant, but 30° below the marksman, the table shows that the back-sight must be set to 245 yards, so as to hit the object. An inspection of the table shows, that, unless the angle of elevation be very conspicuous, it is not worth while to alter the sighting at all when firing up-hill, at all events at short ranges, up to 400 yards, although down-hill will require some attention. After 600 yards, it appears that the sighting must always be raised more or less beyond that of the direct distance when firing up-hill.

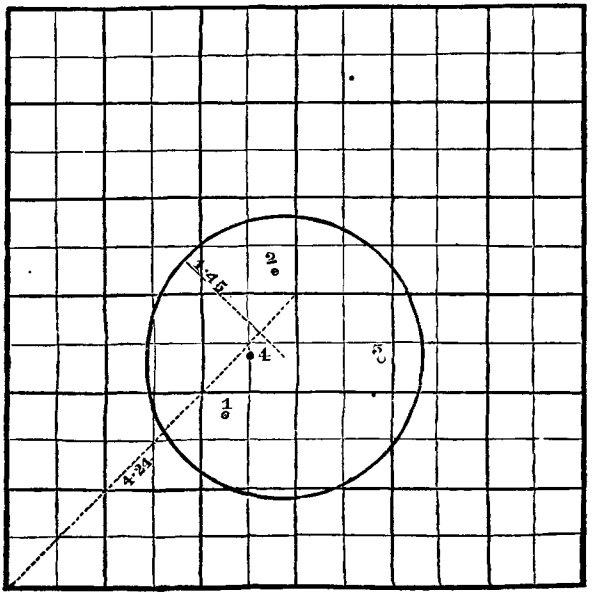
"In the table the distance in yards at the top of each column is the direct distance from marksman to object, as the horizontal distance cannot well be ascertained. The first column is the pitch or angle of the object with the horizon, and the remaining columns contain the distances in yards to be set on the back-sight, so as to reach the object at the respective direct distance."

TABLE for ANGULAR SHOOTING.

Angle of object with horizon.	Direct distance to object in yards.					
	100	200	300	400	500	600
UP.						
45°	77	161	256	354	454	596
30°	92	190	286	397	503*	612*
15°	99	201*	305*	411*	517*	623*
LEVEL.						
0°	100	200	300	400	500	600
DOWN.						
15°	94	187	277	371	477	552
30°	81	163	245	327	407	473
45°	65	127	203	269	334	401

APPENDIX G.

DIAGRAM SHOWING THE MEAN ABSOLUTE DEVIATION OF 5 SHOTS.



6 feet square.

No. of Shots.	Measurement.		Absolute Deviation.	Remarks.
	H.	V.		
1.	2·27	1·76	0·87	
2.	2·76	3·20	0·84	
3.	„	„	4·24	Miss.
4.	2·65	2·35	0·31	
5.	3·87	2·30	1·00	
Total . . .	11·42	9·61	7·26	
Mean . . .	2·85	2·40	1·45	

Method for Ascertaining the Mean Deviation and conducting Experiments.

The position of the bull's-eye must be fixed by a few trial shots, so that all, or as many as possible, of the shots may strike the target, and aim is always to be taken at the same point. A diagram must be kept on which each shot should be placed according to its position upon the target; each shot to be measured horizontally from left of target, and these horizontal measurements to be totalled and divided by number of hits, thereby obtaining the mean horizontal measurement. The mean vertical measurement is obtained by measuring vertically from the bottom of target; the total divided by number of hits gives the mean vertical measurement; the intersection of these two measurements on the diagram will determine the point of mean impact; the absolute deviation of each shot from the point of mean impact will then be found by measurement and applied to the scale; and the mean deviation, by adding the absolute deviation of every shot (including the absolute deviation allowed for misses), and dividing the sum by the total number of shots fired. A circle, described on the diagram from the point of mean impact, as a centre, with the mean deviation as a radius, will show at a glance the merits of the arm, &c. &c. The distance of the point of mean impact from the mark aimed at is calculated in the same manner

as for the absolute deviation of each shot, and denotes the error due to wind and defective sighting. The allowance for misses should be half the diagonal of the target.

By a recent order, in conducting experiments, or testing the accuracy of rifles, each diagram is to record the result of not less than 10 or more than 20 shots. The method of determining the mean deviation to be the same as above described for 5 shots.

For testing the accuracy of rifles, the firing is to take place at 500 yards, at which distance "a mean deviation of over three feet is to be considered a sufficient inaccuracy to condemn a rifle." When the trial is to determine the relative value of two or more rifles, projectiles, or descriptions of powder, then the shooting should take place at least at three distances. The size of the target to be 6 feet by 8 feet if shooting at and under 600 yards, and 6 feet by 12 feet if shooting beyond 600 yards.

In the diagram is to be recorded the name of the firer; the distance; the number of rounds fired; the object of the trial; the description of arm, projectile, or powder under trial; the weight of charge; the weight of bullet; the strength and direction of the wind; the state of the thermometer, barometer, and hygrometer, if these instruments are available; and the state of the loading; with any other information which may be considered desirable to elucidate the diagram.

LECTURE V.

[Fifth Lesson, Red Book, p. 26.]

Rifle Trajectories and Judging Distance.

I. Our lecture this morning is intimately connected with one of our drills, namely, that of judging distance. It arranges itself under the following categories:—

1. The power of being able to judge distances.
2. The necessity of judging distances for all troops armed with the *Enfield*.
3. The *reason why* such a necessity exists.

First, as to the power of being able to acquire the art of judging distance. There is an old saying, that "you may take a horse to the pond, but you can't make him drink;" and so we may take soldiers out to judge distance—to judging distance drill, as we call it—a hundred times without their learning anything by it. The reason is obvious; it is difficult to learn anything we don't believe in; and I fear, if the truth were known, there are a great many disbelievers, doubters, sceptics in judging distance,—that is to say, even in the possibility of acquiring the faculty of judging distance—by which we mean the faculty of closely approximating the estimate of the distance between ourselves and a distant man, horse, or other object.

II. This scepticism mainly arises from the suddenness, so to speak, with which men are called upon to exercise a faculty which, although more or less innate and latent in all

of us, has never been practically applied or exercised. It is an established fact, that if we allow any of our faculties or powers, whether of the mind or the body, to remain long idle and unexercised, that faculty becomes weakened and impaired. For instance, take a man who, at an early age, has been thrown into a dungeon, such as our forefathers used as a prison; or into the terrible French Bastille, significantly called *duresse*, that is, hardness, cruelty—

"Where never sun-beam pierced the solid gloom;"

on being released, after a lengthened imprisonment in such a prison-house, it was notorious that, owing to the forced continued inaction of the mind and body, every faculty of the man was impaired, but most especially his eye-sight. Again, it is well authenticated that blindness is super-induced in horses by their being kept in dark stables. Nay, it is also a fact that the same thing occurs in nature. Of what use would be eyes in fishes that swim in underground lakes? Now it has been found that such fishes are deprived of sight. You see the form of the eyes, but they are only "rudimentary," as naturalists express it.

Now, so far as judging distance is concerned, we may almost say that "we have eyes and see not,"—simply because we have never been placed in a position to train and develope the faculty. We think it impossible to remove the accumulated rust of years that dims it; and, because we cannot at once find a "royal road" to judging distance, we conclude that its acquisition is impossible; and ascribe all the points gained by our right or left hand neighbour at the drill to mere accident, or what is called "guess-work" or "fluking!" Now, judging distance is to be acquired; the difficulty of the achievement is to be overcome, just like any other, by attention to the simple rules by which it is

taught and perseverance in the practice. The "untutored Indian" of the western wilds is an adept in judging distance, since he can give his missile, whatever that may be, stone or arrow, the exact elevation required to hit an object—and what is that but another term for judging distance? He can hit an object, whether that be a man or a monkey, just as easily as he can tell you the hour of the day by observing the sun's height above the horizon. And did not our forefathers judge distance when they gave their "broad-cloth shaft" the necessary elevation for hitting at every distance from one to six hundred yards? Surely, then, what was done in their day with bows and arrows can be done in ours with rifles; and we are in a position to say that it has been done. This is fully proved by the accumulated returns from the Hythe and Fleetwood Schools of Musketry, which establishes the fact beyond all doubt. And as an exemplification we may quote the following summary of the results of judging distance practice during the last four years. Out of 902 officers there trained in judging distance, without including the Volunteers, 669 passed into the first class; and out of the 3,625 non-commissioned officers and privates 2,849 passed into the first class; in other words, taking all ranks together, officers, non-commissioned officers, and rank and file, no less than 77 per cent. could judge distance between fifty and nine hundred yards: while it appears from the Annual Report of the progress of Musketry Instruction in the Army for the year 1861-2 that out of the 121,423 "exercised men" the per-centage in the first class judging distance was 80. Thus, making every allowance for a certain amount of collusion, or what is better known as "chiselling," the fact remains apparent that the majority of soldiers, provided they have average eye-sight and an ordinary amount of intelligence, can be trained and taught to

judge distance with a sufficient degree of accuracy for all practical purposes.

III. Having thus shown the possibility of acquiring the art of judging distance, and, I trust, dissipated all lingering doubts thereon, with the hope that you may one and all persevere in your efforts to overcome the undoubted difficulty which it presents at first, I shall now pass on to the consideration of our second category, namely, the necessity of judging distances for all troops armed with the *Enfield* rifle.

For the most part we are too apt to rest satisfied with becoming tolerably good shots, at targets placed opposite to us, at fixed and known distances, forgetting that in the field of active service—which after all is the only proper medium through which to regard the efficiency or non-efficiency of the rifleman or soldier—unless we can at least judge the distance at which the enemy is from us with a certain degree of accuracy, and adjust our sight accordingly, we might almost as well, for all practical purposes, be armed with the smooth-bore gun of a century back. A striking illustration of this is given by a writer in Blackwood's Magazine, in his description of the equipment of the Garibaldians, immediately prior to the battle of Melazzo, in Sicily. He there states: "For the most part the force was armed with 'Enfields,' but few knew how to develope the use of that deadly weapon, the sights being deemed a superfluity." The question naturally suggests itself to the reader, Why were the sights thus deemed superfluous? and the obvious answer is, that it was mainly, if not entirely, owing to those men, thus armed, being utterly ignorant of and deficient in the power of judging distances.

At the present time, what would not the contending armies in America give for a thorough knowledge of

judging distance—so that they might be able to turn to some account the beautiful rifles with which, for the most part, one side, at all events, is furnished? Nothing can afford a stronger proof of the necessity of judging distance than the comparatively slight effect of the introduction of the rifle into the armies in question. Undoubtedly this results from exactly the same cause as that just mentioned. Indeed it is notorious that the mass of the armies, especially that of the North, is merely a crowd of undisciplined, untrained volunteers—but yesterday plying the quill, the plough, or the shovel.

Just try and realise for yourselves—those who have not already done so practically—this necessity as it would present itself to you in the field of battle, with a hostile regiment or other portion of the enemy's force, steadily advancing towards you from a position, say 600 yards off. Nearer and nearer they come, gaining 100 yards, perhaps, in every minute of time. Of what paramount and vital importance—what a matter of life and death—it would be to you—whether you are there as captain, sergeant, or private in the ranks—to be able to tell when the foe is at 500 yards—then when he has reached 400—when he has reached 300—200—and 100 yards—so that, as he approaches these distances, you may calmly and confidently adjust your sights accordingly, and greet him with an accurate and truly "murderous volley." The chances are, with *well-taught British* soldiers, he would never approach much within the last-named distance.

We witness now every year at Wimbledon a magnificent spectacle of rifle-shooting; but take some of those crack Wimbledon shots, and place them in an open country, in an Indian jungle, or a Chinese rice-field, and, without telling the distance, ask them to hit an object the size of a

man, some considerable way off, and they will at once frankly admit their inability to do so. Judging distance is ignored at Wimbledon, and perhaps for divers reasons necessarily so; but so long as we have a rifle furnished with a back sight requiring adjustment, or retain any pretension to be practical soldiers, we cannot ignore its absolute necessity. To sum up in the exact words of the book of musketry instruction: "It is of no use the soldier being a good shot at a fixed mark if he cannot hit the enemy in the field; *this is the object* of all his training."

So much for the necessity of being able to judge distance in the case of all troops armed with rifles. It now only remains for me to show the reason why this requirement exists with regard to the *Enfield* rifle.

IV. It has already been shown (Lecture III.) that, in order to hit any small object, it is necessary that it should be precisely at the point of second intersection of the trajectory with the line of sight.

But, fortunately for us as practical soldiers, the objects we are taught to aim at and hit possess a considerable degree of height; thus the average height of an infantry soldier is assumed to be six feet, and that of a cavalry soldier on horse-back eight feet six inches;—hence it follows that not only should we hit these objects when at the point of intersection, but equally so within certain limited distances on either side of that point.

Let us give this a definite application. If the Enfield rifle is taken, and the sighting or elevation for 100 yards made use of, matters are so arranged, that, if aim be correctly taken, the bullet would pass through the centre of a man's body at 100 yards distance; but as the bullet, when fired with this elevation, never attains a greater height than 4 feet 6 inches, where in fact it culminates—and as it does

not make its first graze or strike the ground till 195 yards from the firing point—it follows that not only will the bullet hit a soldier in the waist-belt, when standing a hundred

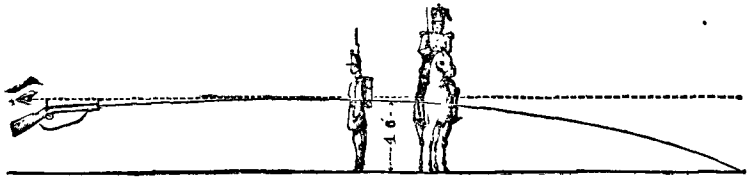


Fig. 36.

yards off, but it would hit him equally somewhere higher, even were he to advance to the muzzle of the piece; and on the other hand, even were he to get 195 yards off, he would there be hit in the feet; and so be unable further "to take to his heels."

Thus it appears that practically no one could stand in the direction of the line of sight for a distance of 195 yards with impunity; and this distance constitutes what is technically and significantly termed the "dangerous space" for an elevation of 100 yards.

With the elevation due for 200 yards, the bullet culminates at a height of 5 feet 4 inches from the ground, and makes its first graze at a distance of 280 yards from the muzzle, so that we here again have infantry under the power of our rifle throughout the entire flight of the bullet.

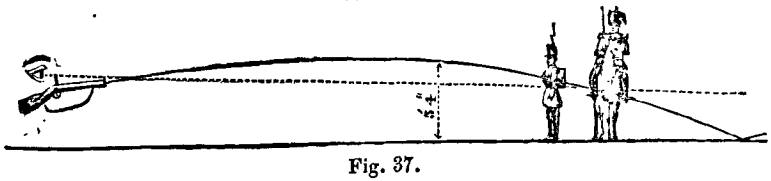


Fig. 37.

Moreover it is worthy of remark, that the bullet rebounds or ricochets at very nearly the same angle as that with which it strikes the ground; and, as at this and other short ranges that angle is comparatively low and flat, it follows that we may with a certain degree of prudence, having due regard to the nature of the ground, calculate on an effective ricochet-fire of at least some 20 or 30 yards further, so that practically it may be averred, that if the sight is adjusted to 200 yards, and the rifle be held straight, some part of a man must be hit throughout a distance of 300 yards, irrespective of any further power of judging distance than is required to tell the difference between one yard and 300—a useful fact this to be borne in mind by a sentry on outlying picket, if taken by surprise.

So much for the trajectory in reference to infantry soldiers at those two ranges. Slight reflection is required to perceive that Cavalry would fare no better, but rather a degree worse, inasmuch as they would be equally under the influence of our bullet throughout its flight, while at the same time their greater height affords a larger target for aiming at, and the disadvantage of this greater height makes itself even more apparent to us, in reference to the trajectory, at the next and following distance of 300 yards.

With the elevation for 300 yards, the culminating height of the bullet is 7 feet, and its first graze 370 yards from the firing point, giving as a dangerous space for the Cavalry soldier on horseback, with an average height of 8 feet 6 inches, 370 yards; and, considering the nature of the ground over which Cavalry must of necessity act, and their greater height, it certainly would not be too much to assume that we may depend on the effect of ricochet fire for some 30 yards beyond the first graze; hence we arrive at the important conclusion, that, admitting you are to judge of dis-

tances, all that an Infantry soldier need do if attacked by Cavalry is, to adjust his sight to 300 yards, and calmly wait till his mounted enemy come within the fatal distance of 400 yards, in order to make him bite the dust; for such is the lowness of our trajectory here, that you cannot miss him.

As a proof that I am not at all exaggerating the effect of ricochet fire at these distances, I may adduce the melancholy instance of the death of Captain Collins of the 26th regiment, from the ricochet of a bullet fired at the Curragh of Kildare. "A party of soldiers were firing volleys at the usual distance of 400 yards, when, as Captain Collins was crossing the range in rear of the target-butt, at a distance of some 1,100 yards from the firing party, a bullet, doubtless fired with more than the necessary elevation, passed over the butt, making its first graze at about 900 yards from the firing point; it appears then to have made a ricochet of some 200 yards, striking Captain Collins in the heart and producing instant death." That the bullet had first ricocheted was proved by the fact of blades of grass being found imbedded in the lead.

Thus far it must be very satisfactory and consolatory to such as would seek a "royal road" to judging distance to know that we are not absolutely dependent upon every soldier knowing the exact distance of an object, for, from the height of the trajectory and its comparative flatness at the ranges to which I have just referred, we are, to a certain extent, rendered independent of judging distance.

We now arrive, however, at a point where the necessity of being able to judge distance with a greater degree of accuracy becomes clearly palpable; for, as our bullet attains a culminating height of 7 feet when fired with the elevation due to 300 yards, it follows that during a portion of its

flight it would manifestly pass harmlessly over the head of a soldier, *even* were he a giant 6 feet 11 inches in height.

It has been determined by careful experiment, that the bullet would first catch an Infantry soldier in the hair of the head as it were, at 225 yards from the firing point ; at 300 yards, provided aim had been properly taken, it would strike a man in the waist-belt ; and at 370 yards it would strike him somewhere in the feet.

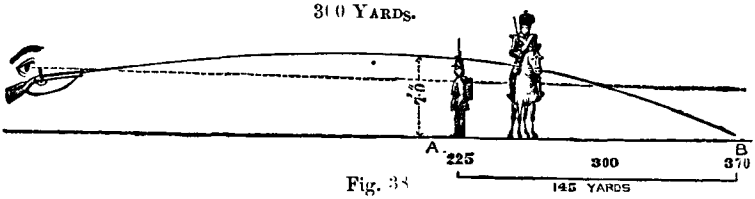


Fig. 38

Our dangerous space, therefore, is now limited to the distance between A and B in the above figure, that is, 145 yards.

With the view of showing that the necessity of judging distance increases with the range, let us proceed at once to trace the course of the trajectory at 600 yards. The bullet now reaches a height of 20 feet before culminating; it first catches an Infantry soldier in the crown of the head at a distance of 565 yards, and strikes him in the heels (making its first graze) at a distance of 635 yards.

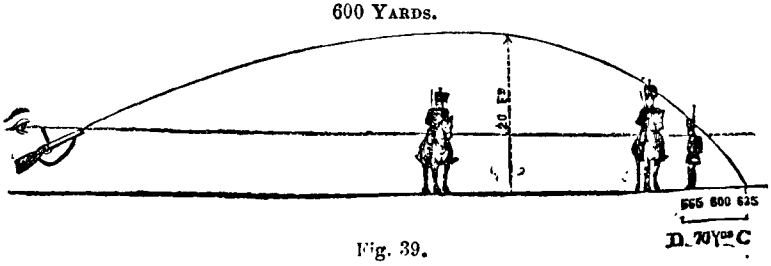


Fig. 39.

Our dangerous space is thus considerably curtailed, lying merely between D and C, equivalent to a distance of 70 yards. The practical inference to be deduced from this is, that to fire with accuracy the soldier should be capable of appreciating the distance of objects so as not to commit an error greater than A B in the first instance, and D C in the second, that being the respective margin permissible in either case for misappreciating the actual distance. In the case of Cavalry, in the latter instance, the margin, owing to their greater height, would be slightly more.

V. In teaching how to judge distances, the recruit is instructed first to take note of the size and appearance of men, placed opposite him, at fixed, known distances ; he has as it were to draw a picture in his mind's eye of these "points for observation," as they are termed; to make, so to speak, a mental photograph of them, so that afterwards when he is called on to judge of men at unknown distances, by a process of inductive comparison, by looking mentally on that picture and on this, he arrives at a correct conclusion as to the number of intervening yards.

Thus his attention is called to the fact, that at 50 yards off, if his sight be tolerably good, he could name any man in his own regiment, as there is, at this distance, complete identification; for the age, complexion, height, and figure of any man can be determined.

The pupil is next placed in front of a man at 100 yards, and made to notice those parts which he can still clearly perceive at this distance, and those which become indistinct. Thus, the lineaments of the face can no longer be discerned; the buttons seem to form a continuous line; the number or ornament on the cap is scarcely discernible from the band, but the different parts of the body, the movements of men individually, and the form and colour of the uniform,

are perfectly distinguishable. At 200 yards the buttons, as buttons, are invisible, and the face looks like a whitish ball under the cap, but the colour of the uniform, the badges of shakos, and cartouch boxes can still be distinguished.

From 225 yards, all the parts of a man's body are still distinguishable by a person with average eyesight; the rifle at the shoulder and the different parts of the uniform are discernible. At about 225 yards we distinguish the colours of the saddle-cloth, the reins of the bridle or horses with dark saddle-cloths, the blade and scabbard of the sword, the shaft of the lance, the carbine slung.

At about 325 yards we distinguish the colour of the saddle-cloth, the reins of the bridle on horses with light saddle-cloths seen sideways, the scabbard of the horseman's sword, the shaft of the lance, the epaulettes on foreign troopers, even the hair of the head.

At about 430 yards we distinguish in infantry the direction of their march, and the movement of their rifles; the saddle-cloth and the rates of motion and direction of cavalry, the helmet and cuirass, the bright colours of the uniform, the shoulder belt of the horsemen seen in front.

At 600 yards the head and lower part of the body are still to be distinguished, but the head appears like a mere ball between the shoulders, which are then never square, but sloped off. We distinguish the rate of motion of cavalry and its direction, the bright colours of the uniform, red, white, the breast-plate, plume, and the blades of the lances; in infantry, the movement of companies, whether advancing or retiring, and the red colour of the French trousers.

At 700 or 800 yards the body has a dwindled, lengthened appearance, but the legs of men in motion, and the arms extended or hanging sideways, are still distinguishable.

At 900 and 1,000 yards the files and movements of troops, and the direction of their march, can still be distinguished.

At 1,200 yards infantry can be distinguished from cavalry.

At 2,000 yards a single man or horse looks like a dot.

The apparent height and size of the object of course diminishes in the exact ratio of the distance. It is the principle upon which *stadia*, or instruments for estimating distance,* are constructed, and though it is difficult with the unassisted eye to take such a mental measure of an object as shall, when compared with its known height or size, enable us to determine its actual distance, yet practice will much increase the power of doing so. Each person should accurately note for himself this apparent diminution, and other changes in the appearance of objects, when studying the "fixed points" at the known distances; thus treasuring up observations, which will be invaluable for the sterner reality of "practice" in the field. Such a necessity is obvious, from the fact that no two men's eyes are exactly alike; nor have they, as a rule, the same notion of colour.

VI. Not only do objects at a distance look smaller, that is, occupy less space in the field of vision, but they often seem actually *to be* either greater or less than they really are; and, if the distance is considerable, almost invariably less. This is owing to an imperfect appreciation of the distance, the object seeming larger than it really is when the distance is less than we suppose, and smaller where the distance is greater. Bearing this in mind, we shall be able to correct our first impressions as to distance when the

* Appendix I. Stadia.

height or size of the object is known as that of a cavalry or foot soldier.

In addition to the foregoing, the men are invariably cautioned to notice the "position of the sun, the state of the atmosphere, and the background," in order that they may be accustomed to the changes made in the appearance of the several objects under different conditions. Thus a body of infantry marching with the sun opposed to them send out strong and constant rays of light in the direction in which they are marching, and are otherwise much more distinct than when the sun is behind; when that is the case no rays are shown. With regard to the state of the atmosphere, it may be remarked, that in foggy or cloudy weather objects having much less light upon them become indistinct, and we fancy them, accordingly, much more *distant* than they are; for, of course, we are apt to judge the distance by what we can and cannot see, forgetting that it is only the want of light that causes the indistinctness. On the other hand, in bright sunshiny days, objects being much more lighted their details become more visible—and, consequently, for the same false reason, appear nearer than they are in reality.

Again, in an avenue of trees objects appear much more distant than they are. This arises from what is called the effect of perspective. The absence or nearness of other objects, the state of the atmosphere, and the effects of light and shade, may apparently increase or diminish the distance in many cases. For instance, a man placed on an elevated ground, with only the sky visible beyond him, will appear much *higher* and *larger*, and consequently *nearer*, than he would under other circumstances; and this apparent height and size will again be modified by the state of the atmosphere, the light of the day, clouds, mist, &c.

The effect of back-ground, however, in judging distance, acts chiefly by the contrast of colour.

The nearer colours approach each other, the more they are likely to blend and destroy distinctness of outline. We can "bring out" or intensify any colour by giving it its approximate contrast. The colours are then said to be *complementary* to each other, or complementary colours. It is in this sense we say :—

Red	is complementary to	green,	and *vice versâ*.
Orange	,,	blue,	,,
Greenish yellow	,,	violet	,,
Indigo	,,	orange yellow	,,

Black and white, which may be considered in some respects complementary to each other, become, conformably to the law of contrast of tone, more different when contiguous than when seen separately. It is by these principles we must be guided as to effect of colour in back-ground as well as to the most suitable colour for uniform where comparative invisibility is deemed desirable.

In Appendix H we append some curious statistics on this subject of the approximate value of colour; by the tables there given, it would appear that grey and brown are least distinguishable at a distance, and consequently perhaps the most suitable for light troops. Rifle-green and blue appear almost black beyond four hundred yards, and, when a soldier clad in either of these colours wears white belts, he offers as conspicuous a mark as the Austrian soldier in his white uniform.

We must not, however, attach too much importance to the supposed advantage of the so-called invisible colours for uniform, in fact at any considerable distance the mass of intervening atmosphere sufficiently modifies and tones down even the brightest colour, and when we come to any-

thing like close quarters it matters not what colour we are in; indeed "the flaming scarlet" has then a decided advantage from its traditional *scaring* effect when worn by the British soldier.

A man placed before any high building, high tree, &c. as before remarked, will appear *smaller and more distant* than he is in reality. Indeed it is very difficult to aim accurately at a man standing near a tree; his true position cannot be accurately defined; we are almost sure to fancy him nearer the tree than he is in reality. Finally, we must never forget to make allowances for the inequality of the ground—risings and particularly depressions between us and the object—as the latter make the distance appear much shorter than the reality.

VII. The modern system of teaching the art of judging distance was anticipated years ago by the practical sagacity of Putnam, the American general, at Bunker's Hill; for he there instructed his men that their aim was to be different according as the Americans could distinguish the waistbands, the faces, or the buttons of our advancing grenadiers; and the consequence was that we left more men before that fatal breastwork than we had often lost in a pitched battle.

A very similar illustration occurred in India. The artillery of the Sikhs, in their last war with us, was so terribly effective that some curiosity was felt about the source whence they procured weapons of such unusual power. Upon inquiry it was found that the cannon were old guns of our own, patched up for use, and all that the Sikhs had done was carefully to ascertain the distance of different points in the line of an advance, and give the guns a corresponding elevation, so as not to throw away a single shot.

VIII. In judging distance practice, so called in contradistinction to the drill, the soldier is taught to apply the

knowledge previously acquired, under the head of drill, by giving a separate individual answer as to his estimation of the distance of men placed at an unknown number of yards from him; when, providing his answer is within the margin permissible, or, in other words, somewhere within the prescribed limits of the dangerous space, as already explained, he receives a number of points in the register kept of the practice, to denote the relative value of his answer; by this plan a healthy spirit of emulation is created.

IX. The foregoing explanation will afford a general clue to the principles upon which the present system of imparting judging distance in England is based—that system is admitted, I believe, to be the best extant, and is used, with but slight modification, throughout the entire continent of Europe, and the *two* Confederacies of America.

Enough also, I trust, has been said, without further multiplying figures, to show the advantage derivable from every soldier being acquainted with every detail connected with the trajectory of his bullet; the figures here alluded to should be familiar as household words in the mouth of every one armed with the Enfield; for, though it is true that instruments have been designed for the computation of distances, in the excitement of battle the soldier would not be capable of using such, and all instruments are thus far unsatisfactory either from giving an inexact approximation, being too complicated, or requiring too much time to use them.

X The admirable stadiometer, now generally adopted throughout the army, is too well known to require any description here, but it may not be altogether irrelevant or superfluous to describe how, in the absence of that instrument, or where the ground is so irregular and hilly as to prevent a chain being laid down, or even if you wish to

learn the width of a river or some inaccessible point, the correct distance may be ascertained by what is called "triangulation."

Fix upon any object B close by the side of the river, on the side opposite to the point A at which you stand; make AD perpendicular to AB; also make AC=CD, and erect the perpendicular DE, and when you have arrived at the point E, in a direct line with CB, the distance DE will=AB, the breadth of the river; for (by Euclid I. 15) the angle ACB=DCE, and as AC=CD, and the angles at A and D are right angles, it is evident that the triangles ABC, CDE are similar and equal.

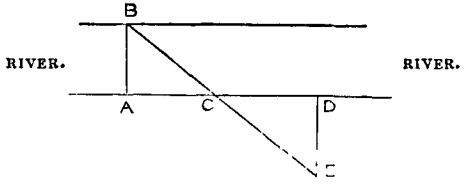


Fig. 40.

But it may possibly happen that the nature of the ground, or the fact of its being commanded by the enemy's artillery, prevents your getting anywhere near the edge of the river—as happened to the Austrians, for example, when Napoleon, having seized on the island of Lobau in the Danube, planted his cannon so as effectually to command the Austrian side of the river for some distance inland—then some such method as the following would have to be adopted.

To find the distance of the French position at Lobau L, from that of the Austrians at the point A?

Throw out a line AC perpendicular to AL and place a pole in the ground at C. Send out a man in the direction of L from C, and place a pole in the ground at D the same

distance from C as A is from C. Drop a perpendicular from D to the line AC at E, and place a pole at E.

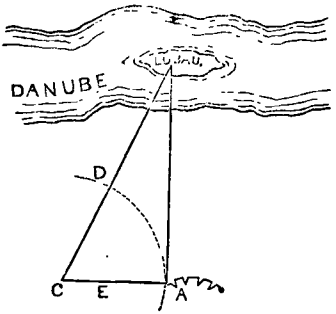


Fig. 41.

Then, by similar triangles, CE : DE :: CA : AL.

XI. After all, an approximation such as the practised eye can give is most to be desired, and there are few men indeed who cannot with a little labour and care attain such proficiency in judging distance as will at least enable them to strike an object the size of a battalion in column at a distance of 900 or 1,000 yards.

Fired with the elevation necessary for 900 yards, the Enfield bullet actually acquires a height of about 50 feet when culminating, and hence the curvature of the latter part of its track is so great that in a measure it may be said to approach the vertical; and herein lies the difficulty of obtaining accurate shooting with the Enfield rifle at this and other long ranges; we have, as it were, not only to fire *at* but *into* an object; the bullet has to be dropped on a man's shako in order to hit him; so that the slightest possible error in the matter of elevation or taking aim is at once fatal: a finer sight than usual will cause the bullet to fall short of the mark, while a fuller sight will cause it to fall over and beyond. Moreover, we now lose the effect of ricochet-fire owing to the high angle at which the bullet strikes the ground.

Even according to the Hythe average, at this distance only 14 out of every 100 shots fired at a target 6 feet high and 12 feet wide ever take effect. Increasing the width of the target aids us comparatively little; the difficulty is one of elevation, not direction. It is owing to this that none but highly trained soldiers, marksmen in every sense of the word, should ever be allowed to fire at long distances (such as 700, 800, and 900 yards) at smaller objects than a column of men or troops, the depth of which, in the direction of the line of sight, would make up in some degree for any misappreciation of distance or effect of faulty aim.

To drop a ball from an Enfield rifle on to a reconnoitring staff-officer at 900 yards is a feat which could be done, probably, by only a few men in the regiment; but, if a hostile battalion should endeavour to advance from 900 yards' distance to 300 yards, every man in a regiment ought to contribute his quota towards its destruction, for there would be no need of nicely timing the discharge or of minute accuracy of elevation.

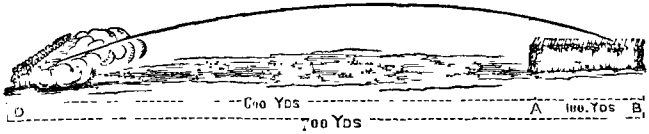


Fig. 42.

Thus if AB (fig. 42) represent a battalion of the enemy in column, with a depth from the front to the rear company of 100 yards, and D a regiment of the opposing force at a distance of 600 yards, we will suppose the officers commanding at D estimate the distance of the enemy's leading company at A to be 700 yards, or that the soldiers at D take a 700 yards' sight. Thus a mistake of 100 yards in appreciating the distance has occurred, but practically

this mistake will make little difference, as the fire will take effect on the rear companies of the enemy, which are 700 yards off.

XII. It becomes apparent then, from what has been said, that the advantages to be derived from a low or flat trajectory cannot be over estimated; most of our difficulty in shooting is owing to the bullet moving in a curved line, and if it were possible to have a rifle to project a bullet in a line, parallel, or nearly so, to the earth's surface, I need hardly say, judging distance would be no longer necessary. The Enfield rifle is surpassed in this respect by rifles which have emanated from private manufacturers, and by none more so than that of Mr. Whitworth, which, so far as reliable data can be obtained, has the flattest trajectory known.

To put the comparative merits of these two weapons in the matter of trajectories in more familiar and definite terms, I may state, that, whereas the curve described by the Enfield bullet at 500 yards (fired at an angle of 1° 30′) attains a height of 15 feet at its highest part, the Whitworth at this range (at an angle of 1° 15′) only acquires a height of 8 feet 6 inches; in other words, the trajectory of the Whitworth, at this range, is more than 40 per cent lower, and therefore better, than that of the Enfield; and the practical corollary which may be drawn from this fact is, that if a body of cavalry were to charge riflemen (infantry) from a position of 500 yards off, the Whitworth bullet aimed for that distance would hit them in any part of its flight, while the Enfield, at the culminating point of its curve, must whistle harmlessly over their heads, though a first-class marksman fired the shot.

Sir W. Armstrong, in discussing this subject in reference to his ordnance at the Institution of Civil Engineers, made

the following observations:—"At 4,000 yards a man on horseback (taking man and horse as an object) subtended an angle of less than three minutes of a degree, and three minutes of elevation was equivalent to only 15 yards in range. Hence, therefore, assuming the gun to be absolutely perfect, unless the distance could be determined to such a nicety as 15 yards, a shot would either fall short of or go over the object." The fact is, that, when fired at very high angles of elevation, the "angles of descent" of the projectiles, whether fired from ordnance or small arms, become so great, that the chance of striking a small object in this manner would scarcely be worth the powder expended—and the ranges of artillery are likely to be confined for military purposes within 2,000 yards, or perhaps, in special cases, when firing at masses of troops, ships, buildings, &c., to 4,000 yards. "Vertical fire" is proverbially uncertain, but when employed for its legitimate purpose, to bombard large spaces, very great and terrible execution can be produced.

And so, although the highly-curved trajectory of the Enfield rifle at long ranges must obviously be regarded as a decided fault, and a weakness, so to speak, in its construction, yet certain exceptional circumstances may arise, under which this very fault may be turned to positive advantage.

In actual warfare it continually happens that troops advance to storm a breach or attack an enemy in position, covered by the fire of artillery. This was done, for example, with admirable result, at the siege of San Sebastian in Spain, and again, in more recent times, with a like success, at the capturing of the Taku Forts the other day in China; in the former instance, howitzers were for the most part made use of; in the latter instance, Armstrong rifled field-guns, fired with a smaller charge and increased elevation.

Now, let us put artillery on one side, and, assuming that it has been prevented coming "to the front," owing to the nature of the ground, want of horses, or some of the other hundred and one accidents liable to occurrence in the best-regulated war, let us see whether, under such circumstances, the Enfield might not, in a modified manner, be made to do the work of the big guns.

We will suppose that a small brigade of infantry consisting of three regiments, each with an effective strength of 600 men, armed with Enfields, but unsupported by artillery, have to attack an open field-work which has been thrown up and occupied by the enemy.

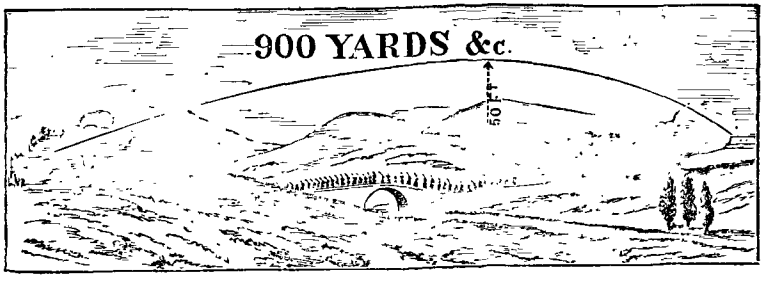


Fig. 43.

The work rests on the crest of a hill, the natural slope of which serves as a glacis, girt at its base by a small stream spanned by a bridge, which, owing to the nature of the surrounding country, constitutes the only practicable approach; the attacking force advances in column across the opposite declivity (or plain) till within range of the enemy's artillery, when it deploys into line, and a further advance is made till within some 900 or 1,000 yards of the enemy's work, and here, while one half of the force continues to move on to the assault, the other half commences firing

volley after volley into the open area of this field-work, over the heads of their comrades, at the easy rate of two volleys per minute, thus 1,200 men would, in ten minutes, project no less than 24,000 Enfield bullets into the Redan, within a comparatively circumscribed area. Beneath such a hailstorm of lead it would be impossible for human life to exist, and the storming party would clamber over the parapet only to find guns deserted and gunners *hors de combat*.

Nor must it be supposed that the occurrence of an incident such as I have attempted to describe, is beyond the limits of probability or fact; on the contrary, it is authenticated that at least upon two occasions during the suppression of the Indian mutiny a similar adaptation of the Enfield rifle was made under nearly parallel circumstances to those here related. But, even admitting that the chances of such a combination of circumstances recurring are few and far between, and leaving out of view the possibility of partially covering the advance of troops by means of Enfield rifle fire, what has been said will at least serve to show that the vertical fire of the Enfield at long ranges may be made use of with admirable effect for siege purposes, where a large area is presented for firing into, for enfilading a redoubt, or hindering a working party throwing up a field-work.

Notwithstanding, however, that so many things may be said in favour of the Enfield rifle, partiality must not be suffered to blind us to its defects. In fact, the trajectory of the "Enfield" is, practically speaking, too much curved. At great distances the bullet plunges, and the "dangerous space" is reduced to a few yards, thus necessitating an elaborate system of judging distance.

Eminent military men of European celebrity have enlarged upon the comparative immunity likely to result to

troops, especially when advancing or retiring, from this enormously curved trajectory. We have shown, however, that many of these surmises are unfounded—the dangerous space being still, so to speak, sufficiently dangerous. But this fact must not mislead us into acquiescence in the admitted defect, if we believe that it can be remedied.

How to flatten our trajectory is, then, the problem to be solved; and a rifle with which "judging distance" would be an unnecessary superfluity should be the object of our ambition and endeavour.

APPENDIX H.

Value of Different Colours.

The following tables (compiled by Major Leveson) will show the approximate value of colour, viz. those that are the least distinguishable at different distances and under various circumstances, and may serve to aid volunteer corps in selecting the most suitable colour for their uniform. The figure 1 denotes the most visible; 7 the least so; 0 invisible.

Colours.	At Three Hundred Yards.								At Six Hundred Yards.								One Mile.
	Open Country.	Wooded Country.	Rocky Ground.	Sea Shore.	Over Water.	Against Sky.	Against Earthworks.	Against Stone Fortifications.	Open Country.	Wooded Country.	Rocky Ground.	Sea Shore.	Over Water.	Against Sky.	Against Earthworks.	Against Stone Fortifications.	
Scarlet . . .	4	3	4	3	2	4	5	4	4	2	5	3	2	3	5	4	5
Green (rifle) . .	3	6	5	4	4	2	4	3	3	7	4	5	4	4	4	3	3
Blue (royal) . .	2	4	4	3	5	3	3	2	2	6	3	4	5	4	3	2	2
White . . .	1	1	1	2	1	4	1	2	1	1	1	1	1	5	1	2	1
Grey . . .	7	6	7	7	7	6	6	7	6	7	0	7	0	7	0	7	6
Brown (dead leaf) .	7	7	7	6	6	5	7	6	7	0	0	6	0	6	0	6	7

Colours.	At Three Hundred Yards Distant.											
	On a Clear Day.				On a Cloudy Day.						Bright Moonlight.	Starlight.
	Daybreak.	Sunrise.	Mid-day.	Sunset.	Daybreak.	Sunrise.	Mid-day.	Sunset.	Rain.	Rain and Fog.		
Scarlet	4	3	3	4	4	3	4	6	3	3	4	5
Green (rifle)	3	4	4	3	7	7	3	0	4	4	3	4
Blue (royal)	2	5	3	2	6	6	3	0	4	4	3	4
White	1	1	1	1	1	1	1	1	2	2	1	1
Grey	7	6	7	5	0	0	5	0	6	6	0	0
Brown (dead leaf) . . .	6	7	6	6	0	0	6	0	6	7	7	7

APPENDIX I.

STADIA.

Various instruments called *stadia* have been contrived for estimating distances, all founded on the apparent diminution of the real height of objects by distance. It may be useful to explain the principle.

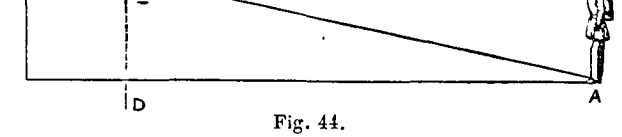


Fig. 44.

Let O be the position of the eye, AC the foot-soldier, and BD the appliance on which we wish to set down the apparent height of the soldier; for instance, a small piece of wood, held vertically at a fixed distance from the eye by means of a string, one end of which is held by the teeth. The length of the string attached to the stadium will be represented by O *b*, say 2 feet.

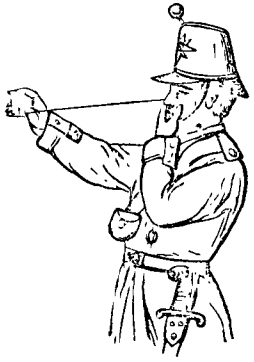


Fig. 45.

The apparent height of the foot-soldier is to be marked on the piece of wood BD by the visual rays which enter the eye from each of the man's extremities.

Now, these two rays, with the real and apparent heights of the man, evidently form right-angled triangles, in which the apparent height *bd* is perpendicular to AC. Consequently it produces the following proportion, OA : O*d* :: AC : *db*.

Assuming the length of the string to be 2 feet, the distance OA to be 200 yards, and the height of the soldier to be 6 feet,—the preceding proportion becomes, 200 yds. : 2 ft. :: 6 ft. : *x*.

Therefore, $x = \frac{2 \text{ ft.} \times 6 \text{ ft.}}{200} = \cdot 72 \text{ in.}$

A similar calculation, made for all the distances, will rapidly give the apparent heights of objects, and they may then be marked on the piece of wood, beginning at one end, as represented in the woodcut in the margin, which is a fac-simile on a slightly reduced scale of a *stadium* on the principle under discussion, brought out by Messrs. Elliott (Charing Cross). To work with this instrument we have only to hold it vertically at the length of the string from the eye, as shown in fig. 46, so that the point of departure of the graduation shall be on the visual ray which comes from the upper extremity of the foot-soldier, and then lower the sliding bar with the thumb of the right-hand until the top of the sliding bar meets the ray which bounds his lower extremity, when the graduation just above the slide will show the distance.

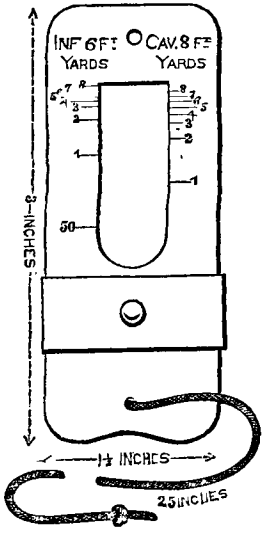


Fig. 46.

This ready tool gives of course only a rough estimate, but perhaps sufficient

for our "margins" on the field of battle. A French corporal, named Malphet, invented a more accurate contrivance.

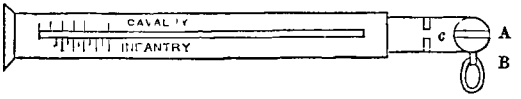


Fig. 47.

This *stadium* consists of a small tube with a slit, as shown in the figure, along the side, and terminating in a funnel to fit the eye. It thus circumscribes the luminous rays, and prevents the trembling of the hand and other inconveniences resulting from too much light.

A smaller tube slides in the first, as shown at A, and can be moved by the ring B. A small stem fixed on this ring fits in the slit of the larger tube and is screwed into the side of the smaller; it thus connects it with the ring, and permits the operator to slide it as he pleases, backwards and forwards. This smaller tube is open at the side nearest the eye, but closed at the other end by a bottom or diaphragm, in which is a transversal or cross-slit *c*, which should be rather fine.

When the funnel-end is applied to the eye, the operator sees the object whose distance is to be estimated through the lateral slit of diaphragm *c*. The object is partly or entirely concealed according to the position of the diaphragm in the larger tube, and we must move the smaller until the two extremities of the cross slit coincide with the extremities of the object. Then the apparent height corresponding to the distance of the object is given by the position of the diaphragm, and we can mark it by means of a stroke on the outer tube, as at D.

Thus we obtain the apparent heights corresponding to all the other distances, whether for foot-soldiers or cavalry; and then the instrument, completely graduated, may be used as previously shown,—the distances being read off on the stroke corresponding to the position of the diaphragm.

LECTURE VI.

[Sixth Lesson, Red Book, p. 28.]

Wind.—Sun.—Defect of Sighting.—Firing at a Moving Object.—Inexact Measurement of Charge.—Pouring in the Charge.—Lubricating Mixture.—Imperfect Bore.

I. The sixth lesson in our Theoretical Principles treats of a number of minor difficulties which present themselves in the practice of musketry. To those of you who are old soldiers or sportsmen, many of these are, no doubt, already known; however, I may say with Pope, that I shall be

> Content, if here th' unlearn'd their wants may view—
> The learn'd reflect on what before they knew.

The theory of many subjects seems easier than the practice; generally because all the circumstances acting in practice are not included among the data on which the theory is founded, and, even when theory is perfect, the muscles and eye have to be taught by practice what the mind may have received by demonstration. No man, for instance, ever learned to ride, to fish, to swim, or to be an archer, by theory alone; and, in like manner, no one could ever become a good shot by the mere study of theory. It is only when taken in conjunction with practice that theory acquires its proper value.

On the practice-ground—or when we go to "the butts"—new conditions present themselves, of which theory, in the strict sense of the term, is not cognisant. Thus, even after quitting the muzzle of the gun, the bullet is affected

by a variety of influences; and a man ignorant of them is surprised and disgusted to find that, in spite of the care and steadiness with which he aimed, he fails to hit the mark.

II. For example, in theory, all our deductions as to the actual pathway of the bullet are based on the supposition that the air, or atmosphere, through which it has to pass, is in a complete state of rest; as it is, for instance, in a room, free from draughts or currents. So far, in fact, we have been considering fine-weather shooting; but, as we have no guarantee that the enemy will come in fine weather, if he comes at all, and as it would hardly do for a general on land to decline a battle because it was "blowing hard," it becomes us to consider, how wind and other influences affect our bullet, and how their effects can be best neutralised or counteracted.

III. A soldier at ball-practice now-a-days, in our army, is almost as much interested in the wind as a sailor; for its strength and direction materially affect the destination of his bullet, and his ultimate chance of getting "prize-money" as a marksman.

Such being the case, it is advisable that we should rightly understand what wind is, how it is produced, and its effects on projectiles generally, and on rifle bullets in particular.

Any lengthy disquisition on the various causes and effects of wind would here be out of place; the following, however, may be taken as a brief explanation of its principal phenomena.

The alternate presence and absence of the sun is the cause to which the disturbances of the atmosphere are to be attributed. This may probably be considered as the sole cause; it certainly is a very principal one. The effect of increased temperature in the air is a dilation, or increase of bulk: the mass so heated and dilated becomes specifically lighter

than the surrounding air, rises up, and its place is supplied by colder air, which, becoming heated, is, in its turn, replaced by a fresh quantity. The ascent of the heated air causes a constant upward current, and the motion of the air, which replaces this, causes a constant current to flow in on each side, from the poles to the equator. The heated air having ascended, flows towards each pole. Thus we have two systems of currents, an upper and a lower current; whereof the upper current consists of the hot air, which, having ascended from the equatorial regions, is travelling towards the poles, and the lower current is the cold air of higher latitudes, which is travelling towards the equator. The interference of these currents produces storms, tempests, and hurricanes,—all effects of the same cause. Local winds have a similar origin. All winds merely strive to equalize the temperature and pressure of the atmosphere.

In effect, then, wind is air in motion, just as a running stream is water in motion. The force of air in motion carries the ship over the sea, and, acting on the arms of a windmill, impels the mill. The tempest agitates the deep, and flings the largest ships, with destructive force, upon the rock. The force of the moving air in the hurricane devastates countries, overturns buildings, and tears up by the roots the largest trees. That so powerful an agent must have an effect on our bullet will therefore be easily understood.

IV. In making allowance for side-winds, the same principle must direct you as would guide you in crossing a stream to an opposite point. Instead of rowing or striking out directly for that point, you would adopt a diagonal course, allowing the current to drift you gradually to the landing-place; and so will your bullet, when the wind blows across the range.

It is well, perhaps, if you can afford it, to take your first

shot right at the centre or bull's eye of the target,—watch narrowly how much it has been carried to one side or the other,—and, in your subsequent shots at that distance, resolutely to make a corresponding allowance.

Great care, however, must be taken in making lateral allowance to carry the foresight along horizontally with the centre of the target, otherwise the firer will obviously be thrown out in the matter of elevation.

Should the wind be blowing down the range towards you —"in your teeth," as the phrase is—the bullet has obviously to meet increased resistance; the particles of air through which it has to force its way are more compressed in front of the bullet, so that, owing to the bullet's increased retardation, it will fall short of the mark. To counteract this, allowance must be made, either by taking a fuller sight—remembering that a fuller sight increases, and a finer sight decreases, range—or by raising very slightly the sliding-bar, in either case giving increased elevation.

A wind from the rear has just the opposite effect; for, though the bullet travels faster than any wind that ever blew, yet in the present instance it encounters less resistance, and the range is therefore extended, requiring a reduction of the elevation usually employed.

The deviation produced by wind increases with the length of the range, nay, it even increases much more rapidly than the distance. Experience alone can be our guide in this matter, after having mastered the principle of the deviations. A side-wind decidedly causes the greatest deviation, for in that case the whole surface of the bullet's side is subject to the influence, just like a ship making lee-way when "sailing on the wind," presenting her whole side to the lateral pressure. Our elongated bullet will obviously be most affected by wind blowing directly from the right or

left, perpendicular to the plane of fire. The degree of allowance to be made, on account of wind, necessarily depends upon the time the bullet takes in its flight, and on which also depends its high or low trajectory. Now, a bullet let fall from a height of 16 feet will deviate laterally from its true course no less a distance than it would if projected horizontally for any distance during a second of time, in so far as the action of wind is concerned, for the time of flight in each case is the same.

The lateral deviation will increase in the ratio of the squares of the time of flight, and therefore, as the velocity of the bullet is constantly diminishing, in a higher ratio than the squares of the intervals of distance. Thus, if a bullet be deflected one foot to the right at 200 yards, then at 800 yards, being four times the former distance, it will be deflected more than 16 feet. Such an allowance has not unfrequently to be made with the Enfield, in practice at 800 yards, owing to its high trajectory, as before explained. We will take another instance. Suppose the wind very strong, say 60 feet per second, and blowing perpendicularly to the plane of fire, experiments show that firing at 160 yards the rifle must be pointed on the side of the wind, about *eleven* inches. Then, as the deviations increase nearly as the square of the distance, the deviation at 320 yards will be at least 11×4, or 44 inches.

It is impossible, however, to fix any rule to meet the variety of cases likely to arise from winds of different velocities blowing from different quarters. A wind acts in a similar way to gravitation, accelerating the lateral motion while the velocity of flight diminishes. The lateral curvature may therefore be assumed to be represented by a curve somewhat similar to that of the trajectory, drawn horizontally instead of vertically.

V. In these days of Volunteer Rifle Associations, with their concomitant rifle-matches at the butts, almost every match-rifle is furnished with a wind-gauge front or back sight, which is capable of being set so as to make allowance at any distance for any strength of wind; thus enabling the firer to aim directly at the mark, and yet make a simultaneous allowance. Mr. Whitworth issues along with his rifle a table, showing the deviations on the target to the right or left at different ranges up to 1,200 yards. This table is calculated on the principle I have just mentioned, and is no doubt a most useful aid to the scientific rifleman.

In the unprecedented long ranges at which the rifle is now used, a very slight current of air passing across the range causes considerable deviation of the projectile; but, if we know the amount of the pressure which the current exerts, the rifle may be so sighted by means of the wind-gauge sights referred to, that unerring aim may be taken direct on the centre of the target even when a hurricane is blowing.

The following table shows the pressure of wind at a velocity of five miles per hour and upwards:

Velocity of the Wind in Miles per Hour.	Perpendicular Force on One Square Foot in Pounds Avoirdupois.	Common Appellations of the Wind.
5	·123	Gentle pleasant wind.
10	·492	Brisk gale.
20	1·968	Very brisk.
40	7·872	Very high wind.
80	31·488	A hurricane.

Dr. Lind estimates the extreme velocity to be 93 miles per hour.

An instrument for measuring the force of the wind is called an anemometer.* Various instruments bearing this name have been devised, but, until recently, none of these have been of a portable character, and many have been extremely intricate in their mechanism. Within the last year, however, Dr. Inman of Liverpool has devised an apparatus specially adapted for the use of riflemen on the target-ground, indicating the relative pressure of the wind and its direction.

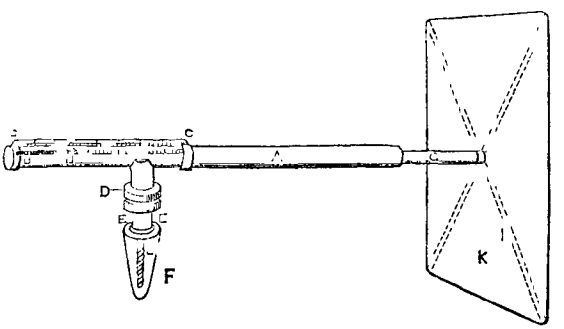


Fig. 48.

The apparatus consists (see diagram above) of a brass tube A 9 inches long, and three-eighths of an inch diameter, with a slot B on the upper side 4 inches long and one-eighth of an inch wide. To one side of this slot is fixed an ivory scale C, divided to half-inches and one-fifths, each half-inch figured 5, 10, 15, and so on to 40. To the under part of this tube A is screwed a steel centre D, which, working in a piece of brass E, and acting as an axle, is affixed by a coarse screw to a piece of tapered wood or cork F about two inches long, to fit the muzzle of a rifle. G is a rod 9 inches long, and one-eighth of an

* From *ἄνεμος*, *wind*, and *μετρεω*, *I measure*. This instrument is said to have been invented by Wolfius in 1709.

inch diameter, fitting in the interior of the tube A; to this rod an indicator H is screwed, which, passing through the slot on the tube A, indicates on the scale C the degree of pressure. To the end of the rod G is attached by a small screw the brass arms or stretcher H, over which, by means of small loops at the corners, is stretched a silk vane or sail 5½ inches square, upon which the wind acts.

In using the apparatus it may be placed at the muzzle end of the rifle, and this "ordered" at about arm's length, or it may be held in the hand by the centre, care being taken that the main tube stands horizontally, and it will be found that a current of wind or air, pressing on the silk vane at C, immediately forces it forward, the amount of such force or pressure being indicated by the pointer on the ivory divided scale attached to the tube. The vane readily presents its surface to the current from the fact of the centre on which the whole apparatus turns being placed at one-third the length of the outer tube, the longer lengths being towards the vane, and thus the end B points to the quarter from whence the wind blows.

In America streamers or long pennants are suspended on high poles alongside the range, and by the angles at which the wind keeps them both its force and direction are estimated. Elaborate or intricate appliances would never do for the practical soldier; but, as it is obviously unfair to compare results obtained under different conditions, it might be worth while to consider whether a record of the wind's pressure should not be kept by means of an anemometer while the shooting is being performed; and whether in regiments shooting should not be discontinued when the wind attains a certain maximum of force.

After all, the most marked effect of the wind is on the

soldier himself, in preventing him from holding his piece steadily. It would therefore be impossible to lay down any fixed rules as to the abatement to be made for wind in shooting, or the distance to "aim off" the target in order to hit it. To be able thus to aim at nothing, so to speak, in order to hit something, requires, I need hardly say, much practical experience combined with judgment; nay, it requires more, it demands a certain amount of moral courage, far greater than that for shaving in the dark.

Our returns exhibit the fact of officers generally surpassing the private soldiers in their *individual* target practice. This result, I do not hesitate to say, is due in no small degree to the difficulty of convincing soldiers of the necessity of aiming off the bull's eye or the target itself; and when convinced they lack the moral courage to carry their conviction into effect; so great is the fascination or attraction exercised over us by the bull's eye.

VI. The next obstacle to good firing to which we have to direct our attention, is positively that without which there could be no accurate firing at all, namely, sunlight. In many circumstances in this world we may have "too much of a good thing;" and such is the case in the present instance.

The relative position of the sun at the moment of firing is apt to influence the aim of the soldier armed with the common Enfield. When the sun is shining on the left of the firer, it has the effect of lighting up the left side of the fore-sight and the right side of the notch of the back-sight; and the result is that the firer is apt, unwittingly, to be misguided by these two bright points in taking aim. A false alignment ensues, the line of sight is made to run across "the axis of the piece," so as to cause a deflection of the axis to the *right*, and the aim is, accordingly, defective,

as we shall proceed to show by fig. 49. The line A B re-

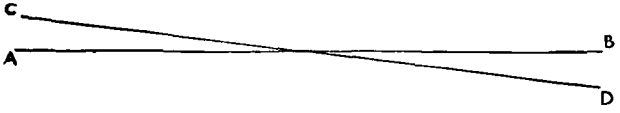


Fig. 49.

presents the line of sight directed on the distant mark or object. C D is the axis of the piece. Let B represent the left side of the fore-sight, and A the right side of the notch of the backsight. Thus, CD being the axis of the piece, it is evident by the figure that it becomes inclined to the right; and thus the bullet must evidently fall to the right of the object aimed at.

This happens when the sun shines from the left. When it shines from the right of the firer, it is just the reverse; our shots are then apt to go to the left.

Perhaps the best safeguard against this deception is to blacken the foresight and backsight, and to take a "fine sight," provided always the mechanical sighting of our rifle admits of a *fine* sight.

For blackening the sights we can recommend the preparation by Blanch, the well-known Liverpool gun-maker; but, in the absence of this prepared article, the soldier will find a little oil and lamp-black, or soot from the chimney, equally serviceable, although less permanent. The India-rubber paper used to wrap up the new Government cartridges affords an excellent sight black when burned underneath the sight.

So much for the effects of sun-light, as far as the soldier in the ranks, armed with the Enfield rifle, is concerned. It might be useless for him to study the subject further; but it is otherwise with the scientific rifleman or the Wimbledon competitor, for whom the foregoing advice has little or

no value, since his foresight, and not unfrequently his back-sight, are thoroughly shaded by what may be termed an iron tunnel or shade. It behoves such a man not only to study the effects of light and shade, but also the barometer and thermometer, in order to determine beforehand the density of the atmosphere, which is found, at long ranges, to affect materially the degree of elevation requisite to secure good shooting.

To those unaccustomed to the thousand and one phases and effects presented by light and shade in rifle-shooting, the difficulty of providing for them may be inconceivable; but Lord Vernon—that Nestor amongst riflemen—has remarked that he would give a handsome prize to any one who would write a good treatise on the effects of light in rifle-shooting. Wind and other influences he understood, and could perhaps neutralise them; but the subtle influence of the sun's light and heat were too mysterious for his apprehension.

VII. It is evident then that the influence of light, or rather its influence on accurate vision, is a subject of considerable importance in accurate target-practice, especially at the long ranges. It is intimately connected with some of the most curious phenomena of optics; but, on the present occasion, we can only glance at this interesting topic. It is a mere truism to state that without light we can see nothing; but it is an important fact to know that we see things accurately only in proportion to their ability or adaptation to reflect or send back towards us the rays of light coming from the sun or other source of illumination. Now, from this fact alone, it is obvious that the surface of the target or other object has much to do with the perception we have of it, at the moment of firing. The greater the polish or smoothness of bodies, the greater is their ability

to reflect the rays of light; but here again we may have too much of a good thing. If the surfaces of bodies were perfectly polished, the eye could scarcely distinguish them. Again, if bodies had no reflecting power, we should be in the same difficulty. If the moon, for instance, had a polished surface, like a globule of mercury or quicksilver, we could not see it, but only the image of the sun by which it is illumined; and if our chairs, tables, and other objects around us, did not reflect light at all, we should never see them! Such being the positive certainties of science, it becomes a question whether we should not ascertain, by direct experiment, the proper surface to be given to our targets to enable us to have a correct idea of their dimensions and position.

VIII. The human eye is the medium through which and by which we obtain the perception of things visible. It is an optical instrument; in fact, to all intents and purposes merely a "dark chamber," into which a small pencil of light is admitted to form an image of the object. The instrument with which your portraits are "taken" is positively the same sort of thing, for all the perfection of art consists in imitating Nature. Place the eye of any animal just killed in the aperture of a dark chamber, after paring away and thinning the posterior surface, so as to present the transparent membrane; an observer within the dark chamber will see very distinctly at the back of this prepared eye the image of any bright object placed before it, just as in the apparatus of the photographer.

Thus the images of objects are faithfully depicted in the eye, or that part of it which is called the *retina;* but, unfortunately, a variety of circumstances interferes with the degree of correctness of the photograph, as in the so-called "correct likeness" for which you pay your shilling, to be laughed at

for your money, and to be asked how you "got that hang-dog look about you?"

To say nothing of the well-known defects of what we call "long-sightedness" and "short-sightedness," it is quite certain that the conditions of the atmosphere very materially interfere with the distinctness of vision. Objects positively appear higher or lower according to the variation in density of the several strata of air around them, by which the rays of light are refracted or bent in their course, exactly as in passing through a prism or lens.

IX. The influence of the sun in producing winds, by the motion of the upper and under currents of the atmosphere, has already been explained (p. 51). There is another phenomenon produced by the sun, which more or less affects shooting on various occasions.

Under certain conditions of the atmosphere the sun produces a source of error, in the form of what is called mirage, caused by an unequal refraction in the lower strata of the atmosphere, which, hanging over the practice-ground, creates an optical illusion, by reason of which our target appears to a certain extent suspended in mid-air, or, at all events, its surface is apparently much dilated or shortened vertically. The effect may be observed in a hot summer day, when the atmosphere in front of the target seems to run along as it were in a stream of greasy water.

It is in Egypt that this phenomenon appears in all its truly wonderful proportions. As the day advances, and the heat increases in intensity, the sand, being much hotter than the atmosphere, heats the strata which are in immediate contact with it. Thus numerous currents are established with greater or less regularity; and there is in the air a species of trembling, which is very sensible to the eye, and the images or appearances of all distant objects are in con-

sequence exceedingly ill-defined: the objects appear to vanish and re-appear at each instant, as if suddenly broken up and decomposed.*

Owing to this ocular delusion or phantom target, more or less reproduced in our latitudes, we are led to take a false aim, and many of our shots consequently go above or below the actual target or mark. The knowledge of this cause of error is sufficient to provide the remedy. This atmospheric effect occurs chiefly in hot summer days, and in the vicinity of undrained land, as at Hythe, from its proximity to Romney Marsh, one of the richest pastures in England.

X. The clearness of the atmosphere is directly connected with the indications of the barometer, which shows the exact pressure of the air at any given place and moment. The degree of pressure, or height of the barometric column, frequently indicates the presence or absence of moisture in

* Properly speaking this phenomenon does not constitute what is strictly called "mirage;" it is when the currents have ceased to disturb the equilibrium of the atmosphere, and the strata of air near the plain remain perfectly at rest, having acquired a high temperature from the hot sand, that the phenomenon of the mirage is exhibited in all its magnificence. A spectator sees the distant eminences, the villages, and all other objects slightly elevated, but beneath them he sees their image inverted, and consequently loses sight of the soil on which they rest. This phenomenon, which was often observed by the French during their expedition in Egypt, was a spectacle equally novel and distressing. The toiling soldiers, when they saw at a distance on the burning plains the reflection of the sky, the inverted image of the houses, of the palm-trees, and of all the objects on the horizon, could not doubt but that they were formed by reflection at the surface of some beautiful lake, which they were only too glad to be approaching. Fatigued by their forced marches under an intense sun, and in an atmosphere full of burning sand, they ran to the imagined water; but, alas! it fled before them! It was only the unusual condition of the heated air which produced this cruel illusion. For further illustrations of similar effects see Appendix K.

the shape of haze or mist, and this condition may be directly measured by the hygrometer; and it is not impossible that we may ultimately be able to collect data which will assist us in fixing the degree of "elevation" required in firing to correspond with the observation of various instruments. It is said that "a word to the wise is sufficient;" and I trust that this hint may induce others much more competent and able, by time and leisure, to solve the interesting problem.

It is notorious to those who have given the subject their attention, that, when the mercury in the barometer rises, more elevation is necessary; on the other hand, when it falls, the angle of elevation must be reduced. Again, more elevation is required at the sea-level than inland, or on high table land. Firing across water also necessitates more elevation; but this, probably, has nothing to do with the water, but simply supplies another fact in the same category, for water-collections are in general on a "lower level," approximating to that of the sea-shore, and a stratum of vapour will doubtless be found in such places.

It is generally admitted, that a bright, clear day is not so favourable as when the sun is overcast; which, I may observe in passing, also happens to be the best time for photographic shots, or taking pictures, with the best-made instruments.

It would appear that practice, either at early dawn, "ere yet the dew has left the grass," or towards sunset, just before the "witching twilight hour," affords more satisfactory results than when conducted in the broad glare of a fine day.

A humid state of the atmosphere seems rather to favour good shooting; and I have frequently witnessed better practice than usual during a downfall of rain, when, contrary to what might be supposed, a *reduction* of elevation was necessary. But this is easily explained by the fact,

that moisture in the air keeps the fouling moist in the barrel; the bullet experiences less resistance from the friction of the bore; and so its *velocity* is less diminished: hence the trajectory becomes flatter, and less elevation is required. The actual resistance of the rain-drops to the bullet is very little.

The exact explanation of these effects is not, perhaps, very difficult. Different densities in the air exert, as we have seen, material influence on the refraction of light; and, consequently, they must interfere with the accurate vision of the object as to its position; so that we elevate merely to counteract the atmospheric deception. But we must not forget, that the *pressure* of the air is indicated by the rise and fall of the barometer. When the barometer indicates the greatest pressure, then we find more elevation required; apparently pointing to the fact, that the bullet meets with greater resistance from this *denser air*, and, consequently, requires more elevation to reach the mark. Thus it is, also, at the sea-level, where the normal pressure of 15 pounds to the square inch generally prevails. In cloudy weather the density is generally less, as we know, and so lest elevation is required, the bullet meeting with less resistance from the comparatively thinner air. On such occasions, also, the air is usually moister. So the moisture in the air may favour the bullet's velocity, as before observed, by keeping the fouling moist; a state of things quite evident to the firer, by his soiled hands from the moist vicinity of the nipple. Thus it appears that the increased or diminished density of the air, together with the increased moisture in cloudy weather, is the cause of the necessity of increased or diminished elevation in the two cases respectively.*

* The above remarks on the effects of light and atmosphere have been submitted to Capt. Heaton, the champion shot of England, and have his entire approval.

XI. Again, the contrast of colours has much to do with the distinctness of vision. Some colours can only "come out," as we say, by contrast, as already explained at page 136.

Now, as eye-sights differ in their capacity, it would be well to assimilate the conditions of prize-firing by placing the target in the best possible condition, by contrast, for securing distinct perception.

Our targets are white, why not give them a black background, by pouring a layer of pitch over the surface of the butt in the rear, whether composed of sand, gravel, or turf? There would thus be nothing to interfere with the distinctness of vision; all would depend upon the skill of the firer; and, undoubtedly, he would score more centres and hits at the long ranges than at present.

Practically there is also no doubt that shooting is favourably influenced by an abundant presence of the verdant hue of nature—green turf, green leaves, green shade,—anything green, in fact, save the firer himself, apart from his uniform, seems to conduce, by the repose it affords to the eye, to good shooting.

The "running man" established at Wimbledon,—our modern *Campus Martius*, this year, represents the figure of a volunteer "at the double;" one side is represented with a grey uniform and the other with scarlet; and it is a remarkable fact, in connection with this target in motion, that the side of the figure represented in a scarlet uniform was hit much less frequently than the grey tunic painted on the other side.

This circumstance might be regarded as an argument in support of the view entertained by military men that scarlet, though the most brilliant, is yet the most difficult to hit. The fact has, however, been explained in the following ingenious manner:—

It appears that against the sky-line scarlet can be picked out at almost any distance: but when, as at Wimbledon, there is a green or any dark background, scarlet *in motion* produces an optical illusion by leaving a deceptive red streak behind, which unsettles the aim of the marksman. Any one can try the experiment for himself by twisting round a lighted stick in the dark; every one knows that it will produce the appearance of a circle of fire, and, exercising merely the organ of sight, and not of touch, it would puzzle even the holder of the stick to say whereabouts exactly the point of the stick was at a given second.

But another explanation has also been offered, on the ground that, whereas the grey-coated volunteer made his run invariably from left to right, the red-coated soldier passed from right to left, and that practically it is more difficult to hit an object moving in the latter direction, as sportsmen are well aware.

In conclusion, the only effectual mode of practically overcoming the difficulty caused by the variations of atmospheric condition and temperature, is to adopt the excellent advice recently given by that "old deer-stalker," Captain Horatio Ross, in a letter addressed to the Volunteers of Scotland, anent the match to be shot at Wimbledon, between England and Scotland. He therein says:—

To most people the economy of time, and, I may add, of ammunition, is a matter of very considerable importance. I therefore wish to assure them that in rifle practice it is not necessary to fire a great number of shots. A man who makes judicious notes of his practice will derive more advantage from firing a hundred rounds than another who expends a thousand rounds without carefully recording the effect of wind, light, and the state of the atmosphere on the flight of his bullets. In addressing practical riflemen, it is hardly necessary to remind them, that, at long ranges, the angle of elevation which suits them for to-day is rarely adapted for to-morrow. To ascertain the causes which lead to this rather mysterious result is the first step to

become a scientific rifleman. I therefore recommend you, before you commence practice, to make a note of the barometer, the direction and strength of the wind, and the light; and, when you have made three successive bull's-eyes at any range, to be satisfied. More practice at that range is not required for that day. Note carefully the degrees and minutes of your back-sight, and also of your wind-gauge. By attending to this, in the course of time you must have in your possession a great many observations, and will not be at a loss in any weather as to the elevation or allowance for wind that is required.

XII. It seems almost unnatural to blame the sun for our bad shooting; and it might sarcastically be asked—how we could shoot in the dark? It so happens, however, that the question well deserves an answer. We may actually have to shoot in the dark. Suppose, for instance, a soldier were acting sentry at an outpost which guarded an approach to the camp;—how, in the darkness of the night, would he know how to deliver his fire in the direction of that approach? His best method would be by fixing, before night-fall, two sticks, some 4 feet 6 inches in height, with forked ends, in the ground perpendicularly, so that when a third stick, or the rifle, were laid horizontally across the

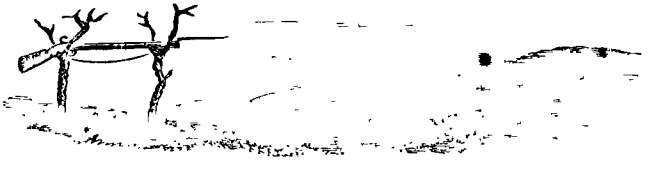


Fig. 50.

two forks, it would exactly indicate the direction from which the attack must be made.

XIII. Again, on active service, it may happen that the object against which you are firing becomes temporarily hidden by the smoke of battle;—thus, if you were firing at horse artillery at a distance of 700 yards, and they became

obscured from your view by reason of the smoke, it would be absurd on that account, especially if you had reason for supposing that they had not changed their ground, to cease firing. The best course would be to place something, a stick or a ramrod, in the ground, and in the direction of the enemy, and so continue to fire at it with your sight raised for 700 yards.

This would at least be better than resigning yourself, Turk-like, to *Kismet*, and sitting down and doing nothing; all that is requisite in firing is to establish a "line of sight," and I have heard of an instructor who got all his men, "lame ducks" included, out of the "third class," by making them aim at a wafer placed on the end of a wire a few yards in front of the firer, and in direct alignment with the target.

XIV. We are told by the Red Book, "it may sometimes occur that the rifle is not accurately sighted as to elevation, and, consequently, may carry a little high or low."

The necessity of sights has already been shown in Lecture III. It might almost be said that they are "necessary evils;" for a variety of evils may be traced to their defective graduation, or their position on the barrel of the rifle. For example; it is often found that the marks placed on the back-sight of the rifle do not indicate correctly the required elevation. This may seem strange, since we know that all the sights and barrels are now made by machinery, according to one fixed pattern; but the truth is, that it is owing to this very fact that such discrepancies occur. For, in reality, it is quite impossible to make two barrels exactly alike. They may resemble each other so as to make it impossible to recognise one from the other, but an internal flaw however slight—a little difference in the closeness of the texture of the iron, may, nay generally does, exist, and so produces a corresponding difference in the result. This internal

difference of the barrel requires a corresponding difference, however slight, in the elevation of the piece; the fact being, that, whilst the sights made for the same "issue" or batch of rifles sent out by Government are really all alike, the barrels are only nominally so.

Hence, every rifleman should narrowly watch where each shot goes, so as to arrive at a correct conclusion as to the elevation for that range; nor must he jump too quickly to the conclusion that he has found the correct sighting.

The elevation differs with the state of the atmosphere, as before mentioned; and, therefore, accurate shooting can only be secured by observation of several days firing. There are, perhaps, few things more difficult in rifle-shooting than sighting a rifle correctly; and there is certainly nothing that yields more satisfaction when accomplished.

XV. Moreover, discrepancies in the elevation may occur

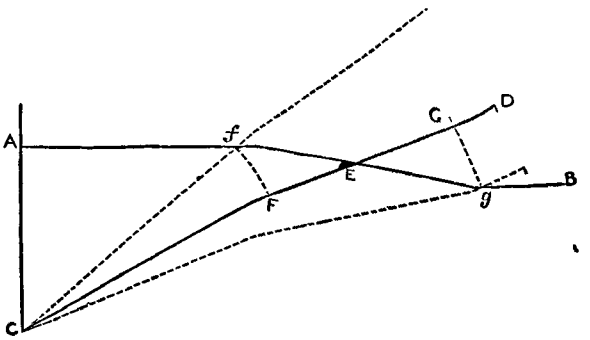


Fig. 51.

from the sights not being fixed at an exact and uniform distance from each other. This may, to a certain extent, be accounted for by the fact that the barrel of the gun may be made by "contract" in Birmingham, the sight at Sheffield, and then put together at Enfield. Be that as it may, how-

ever, the result is, that, if the fore-sight be too near the muzzle, a loss of elevation ensues; and, on the other hand, should the fore-sight be too near the back-sight, the gun will be found over-sighted. This may be illustrated as follows.

Assume A C to be the back-sight in fig. 51, A B the line of sight, C D the upper and outer surface of the barrel. The fore-sight when at E gives, we will assume, the exact elevation required; but, if we imagine the barrel lengthened and the fore-sight moved forward to the point G, we should then have to depress the muzzle from G to *g*, in order to get into the alignment; and by so doing we lose elevation to the extent represented by the angle D C *g*.

On the other hand, if the foresight were brought nearer the back-sight, to the point F, for instance, we should have to raise the muzzle from F to *f* to get into alignment, and thus increase our elevation by just so much as the angle *f* C D represents.

XVI. Again, the use of a fine or coarse sight materially influences elevation. Thus in fig. 52, with a fine sight over

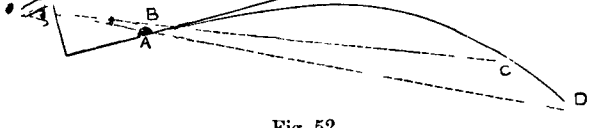


Fig. 52.

the fore-sight, the range is shown to extend to C; but when a coarse sight is taken, so as to pass over the base of the fore-sight, or if we take in the whole of the fore-sight, the range becomes extended to D; or, if the line of sight remain the same with a full sight, the elevation is increased, and the ball carries higher.

A thick, coarse fore-sight, with a broad base, has another disadvantage.

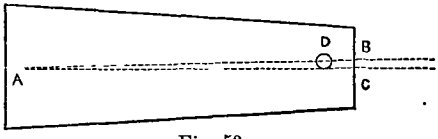


Fig. 53.

Aim is apt to be taken to the right or left of its side; and, as shown in fig. 53, where the aim has been taken by the right side of the fore-sight, the line of sight AC and the axis of the piece AB are no longer in one plane, and thus shooting becomes injuriously influenced, just as in the case of the sights having been misplaced on the barrel.

XVII. Other causes of inaccuracy may depend especially on the arm. The sights are very often not fixed exactly over the axis of the piece. The fore-sight, for example, may be placed too much to the right or left of the vertical plane of the axis.

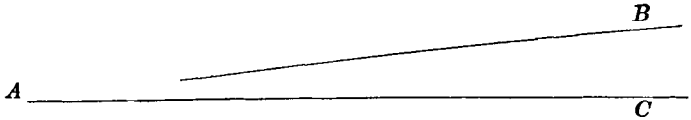


Fig. 54.

Suppose, in fig. 54, A the back-sight, and AB the axis, and C the fore-sight, too much to the right. Then, as the alignment would be made between A and C, irrespective of the deflection to the left of the axis of the barrel, the bullet would obviously be carried off *to the left* in the continuation of AB. Again, if we assume AC to be the axis and B the fore-sight, placed too much to the left, then the shooting will be off to the right; so that in neither case will the mark be hit.

XVIII. The back-sight may be either too much to the right or left. Thus, using the same figure, and assuming B as the back-sight placed too much to the right of the true axis of the barrel CA, of which A forms the foresight, then the shot will obviously move off to the right, in the direction of CA, extended to the extent marked by the angle CAB.

Reverse the position, and make C the back-sight placed too much to the left of the axis BA, and the shot will carry to the left, in the direction of BA prolonged.

XIX. If the sights are not placed exactly over the axis of the piece, it is absolutely necessary to counteract the defect. Either a radical change must be effected in the position of the sights themselves by the armourer, or appropriate allowance must be made for the error on all occasions by the firer; which latter is neither very agreeable nor very easy, especially when combined with the other impediments to accurate shooting, already sufficiently numerous.

I have now enumerated and discussed most of the defects likely to exist in the sighting of the ordinary rifle. It is well to pay attention to such remedies as are here suggested, or to such others as may be made obvious by the nature of each case as it presents itself, without being obliged constantly to call for assistance from the armourer-sergeant; since the target-ground should be the preparation for the battle-field, where the aid of armourer-sergeants is, of course, utterly out of the question.

But the importance of accurately fitted and carefully adjusted sights to any rifle before good shooting can be made with it, is so great, that we feel justified in adding here, for the benefit of riflemen generally, a few remarks descriptive of some of the newest appliances contrived to accomplish this desideratum. For, no matter how excellent the barrel of a rifle in itself may be, nor how steadily the shooter use

it, unless the means of making a perfect alignment are secured, even the best weapon in the best hands can never attain anything like perfect shooting.

Of all the annoyances which affect the rifle-shooter—and they are not few—perhaps one of the greatest is having to make an infinite number of little lines or scratches, in addition to the arbitrary lines fixed by the gun-maker, to denote the shades of variation in elevation caused by particular lights, winds, or other exceptional atmospheric conditions, the very meaning of which will frequently escape his memory. Any arrangement, therefore, which precludes the necessity for making such marks must be regarded as a decided advantage. This is effectually attained in Blanch's Vernier back-sight. The Vernier, named after its inventor, Peter Vernier, a Frenchman, was invented early in the seventeenth century, and is an instrument adapted to the measurement of very minute spaces and divisions. A good example of its use and action may be found on most barometers, where the atmospheric pressure is measured from the top of the column of mercury. The usual scale on such barometers is about four inches in length, the inches being divided into tenths. The Vernier admits of several varieties of scale as well as form, but the principle is the same in all.

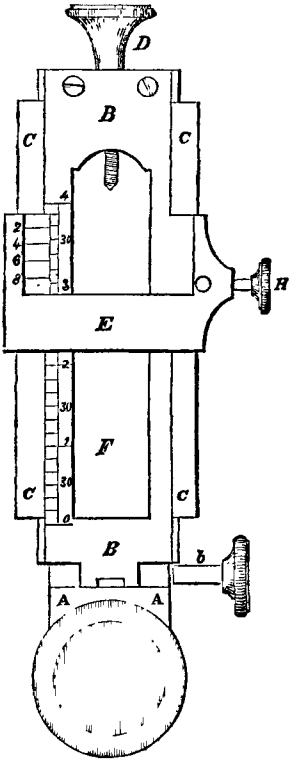


Fig. 55.

It consists in having a small moveable scale by the side of the fixed scale, so divided that each of its divisions, which are usually ten in number, are one-tenth longer than those of the fixed scale. The upper edge of this moveable or Vernier scale is adjusted by means of a screw to the height desired to be measured, and its height above the next graduation of the fixed scale is shown by the number of divisions on the Vernier scale above the point where the graduations of the two scales correspond.

In the Blanch sight, as described by himself in his "Volunteer Book of Facts," the scale on the leaf contains four degrees, that is, 4-360ths of the circle of which the distance between the sights is the radius, and, as each degree is subdivided into six spaces, each space contains ten minutes.

With a distance of 29 inches between the sights, the length of a degree is ·506, or about half an inch, and as the Vernier will read easily to one minute, or the sixtieth part of half an inch, and as few rifles have a degree so long as this, it is evident this division is near enough for all practical purposes, a minute making a difference in elevation of a very small fraction more than an inch at one hundred yards.

The Vernier sight enables the bar to be moved a distance which would be inappreciable to the eye without the assistance of a microscope, and to register a quantity by exact measurement, so small, that if the scale had been divided into such spaces the lines would have become invisible from contiguity. To accomplish this the leaf of this sight is divided into two parts, the outer portion being accurately fitted and dove-tailed to the inner one, upon which it can be moved about a quarter of an inch. This movement is communicated to it by a micrometer screw working in a head-stock secured to the top of the inner leaf, by which means a difference in the elevation of the sliding bar of 1-1000th of an inch may be made if desired. The sliding bar, with its Vernier attached, is moved upon, and secured by, a small binding screw to the outer frame, as nearly to the required reading as possible, by the mere movement of the fingers, when its accurate and final adjustment is effected by the aid of the micrometer screw, which adjusts both frame and bar to the

elevation required. The degree on the Vernier is divided into five spaces of 12 minutes each, having an excess over those of the scale of two minutes. The Vernier will therefore read to two minutes by its lines, to one minute when one line has passed and the next not reached its adjacent scale line, and to a fraction of a minute by the micrometer screw. The scale is engraved upon a strip of platinum, and the face of the Vernier which runs flush with it is also of platinum, to prevent obliteration of its lines and figures by corrosion. The following, among others, are the advantages of this method of sighting a rifle. The arbitrary lines for the different ranges, which *can* only be correct for those ranges under precisely similar circumstances of wind and weather, and which consequently are incorrect under all other circumstances, are abolished altogether. The correct elevation for each range having been found by actual shooting, and read off from the Vernier, is noted in the field-book, say, for example, at 500 yards 1° 16′, or one degree and 16 minutes. If after a number of trials on different days, without wind, and in a good light, and under the same atmospheric conditions, this should appear to be the correct elevation for 500 yards, then 1° 16′ may be considered to be the mean elevation for that distance, and may be so entered in the note-book. But other circumstances will sometimes cause a difference from this reading, above or below it, of several minutes, and it is then that the advantage of the Vernier is most appreciated, as the exact distance above or below the mean reading can be measured by it, and may be also noted in the book, together with any remarks for future guidance upon the peculiar conditions which caused such deviation, thus, wind S.W. left rear, very strong, barometer 28·76, 500 yards, Vernier reading 1° 11′. The elevation for such a day would have had to be recorded upon an Enfield rifle by a scratch with a knife below the arbitrary line professing to give the elevation for that distance; but the note-book shows by the assistance of the Vernier that the elevation was exactly five minutes lower than the mean on that occasion, and on a similar one will enable the shooter to place the sliding bar in precisely the same position. The trajectories of rifles thus sighted can also be compared, and their relative merits to a certain extent ascertained, as the degrees and minutes indicated are the real degrees and minutes of elevation, and give the angle of elevation with sufficient accuracy for that purpose; the only error being the very slight one that arises from the leaf of the sight

being flat instead of its having the curvature of its proper circle. Having found the elevation for any one range, it may be found for any other by adding or deducting the number of minutes in accordance with a scale furnished with each sight. This sight is also furnished with a darkening leaf, which most effectually shuts out all reflected light below the sliding bar, which, from the simplicity of its construction, is not likely to get out of order from rust or any other cause.

The *aperture sight*, which has of late been a good deal used, consists in its simplest form of a round hole for the fore-sight and another on the back-sight. The eye is placed close to the latter, and the aiming of the rifle brings the fore-sight so that the bull's-eye is seen in the centre of it. In a later form the fore-sight aperture is a vertical line between two shoulders, which nearly touch. In another the aperture back-sight is used with a bead fore-sight.

It is evident that much light is shut off by all these plans, and therefore the aperture sight is useful chiefly at short ranges, unless the day is bright and the air clear. A funnel, or cone-shaped tube, of soft leather or india-rubber closing round the eye as it looks through the back-sight, is frequently used to exclude external objects, and fix the attention on the sole point of aim, the bull's-eye on the target.

Another sight which has now obtained deserved celebrity is the Orthoptic* Screen Sight of Dr. Goodwin, of Southport. This invention involves the constant use of *three* sights or points of alignment on the rifle, and the advantages claimed for it are, amongst others, as follows :—

1st, that when the sights are correctly aligned for any range the shooter cannot vary his shots from any cause except unsteadiness; *i.e.* cannot take a finer or fuller sight, or take his aim without seeing the bead of the fore-sight exactly over the platinum line of the back-sight, which is frequently done through inadvertency where two sights only are used; and 2ndly, that a much clearer and better view

* ὀρθὸς—*straight;* and ὀπτικὸς—*belonging to sight.*

of the target and sights is obtained by the exclusion of all light from the front except those rays which proceed direct to the eye through the small hole in the screen or eye-piece.

This sight can be attached to the stock of any rifle by means of a small foot-piece, by screws. It consists of an upright bar or rod of steel, upon which the frame which carries the disc and its eye-piece moves up or down, either by the use of a rack and pinion, a long screw, or a simple slide, at the option of the shooter, to the required elevation, where it is secured by a binding screw. The eye-piece, which is contrived to hold two or three differently-sized discs, to be used according to the quantity of light, has a traversing horizontal motion in its frame, obtained by a micrometer screw, by which the bead is always brought over the platinum line by moving it in an opposite direction to the one used on the fore-sight for any wind allowance. The elevation is taken by the sliding bar of the back-sight, and the wind allowed for on the fore-sight, in the usual way, the eye-piece being then brought into the required position, *i.e.* so adjusted that the bead shall appear exactly over, and apparently resting on, the platinum line. If the adjustment shall have been correctly taken, any deviation from it, or difference in the sighting for any number of shots, is rendered nearly impossible.

The practical rifle-shot will see that a cause of serious error in long-range shooting is thus entirely obviated, and there is no doubt that the wonderful improvement in small-bore shooting at the last Wimbledon meeting was in a great measure due to the general adoption of the "Orthoptic" in some shape or other.

A scarcely less valuable novelty in sights was first introduced at the Wimbledon meeting by Mr. Blanch. It is also the invention of Dr. Goodwin, and is called by him the horizontal bar fore-sight. It consists of a rather broad bar of metal, in the centre of which is a fine vertical slit. This forms a stem of light, to which, in target practice, the bull's-eye itself is made the bead, or termination. By the bar being well defined against the white target, the rifleman can judge better than by any other means whether the

sights are upright; and at the same time can aim higher or lower, with the greatest exactitude, even at the longest ranges, by seeing more or less of the target over and parallel to the top of the bar. The sight consists of two small blocks of steel $\frac{1}{4}$-inch in height, and each $\frac{3}{8}$-inch in length. They can be screwed to the bead of any wind-gauge fore-sight, leaving a vertical space between, which may be varied to suit different eyesights. This line of light is distinct and well-defined on the dullest days—far superior in this respect to the platinum line generally adopted in back-sights. This kind of fore-sight is obviously strong, and little liable to injury; and, while one of the best yet adopted for target-practice, is equally suitable for sporting and even military purposes.

I shall conclude this section by reference to a new sight devised by Lord Bury,* the use of which has been attended with most marked success in numerous instances. Lord Bury's object was to get over the blurred appearance inseparable from the form of back-sight, which renders it exceedingly difficult to tell how much of the bead fore-sight is taken, and, consequently, causes the angle of elevation of the rifle to be varied with each shot. He reverses the V altogether, and shoots from the apex, or rather from the apex flattened to one-tenth of an inch broad, in which he cuts a narrow vertical slit. When looking at the distant target, this flattened apex appears like two sharp points one on each side of the head, the stalk of which is seen between them. There is still however a little blur; to counteract

* A most useful book for Riflemen has been brought out, called the "Bury" register. It contains a full explanation of the new system of marking and scoring, as adopted at Wimbledon; of the wind-gauge; of the Vernier, and how to use it; and then follow tables containing columns for every object a Rifleman should wish to note—his scores, the degrees on his wind-gauge, the results of his practice, with diagrams for entering the place of his shots.

this he stretches a fine wire across the barrel of the foresight at right angles to and one-twentieth of an inch below the head, and fills up the space below the wire with a piece of ivory. The wire, while ensuring the correctness of the angle of elevation, is of considerable value in enabling the marksman to judge whether the sights are perfectly vertical, and the ivory forms a background against which the two points of the apex are clearly seen, while the ground beneath the target, which would otherwise disturb the eye, is completely concealed. Lord Bury on a clear day uses in addition to his own sight a pin-hole eye-piece fixed on to the stock of the rifle in the same manner as Dr. Goodwin's orthoptic back-sight.

A telescope about six inches long, with cross wires, may be fixed to a rifle without any other sights, and with excellent effect. The Confederates have some hundred Whitworth rifles with adjustable telescopes, and thus are enabled to distinguish and kill officers at 1,500 yards

XX. It may appear almost superfluous to advert to the allowance which must be made in firing at objects in motion; but, in point of fact, many a victory has been barren of results, owing to the inability of pouring an effective fire on the retreating enemy, as, for instance, at the Alma; and again, during the late mutiny in India, many a rebel Sepoy escaped with his life because our men were unable to make due allowance for the speed with which he was moving away. Besides, an enemy in the field rarely remains long in one position, like our targets on the practice-ground. They are generally "on the move," skirmishing, getting into new formations, "changing front," or bringing guns into position.

In order, therefore, to make proper allowance, two points must always be taken into consideration: first, the rate and direction of motion of the object fired at; and, secondly, the distance of the firer from the object; as, of course, there is

involved in this latter point the *time the bullet takes in its flight;* and in this practice the exact timing of the shot is "all in all."

Take, for example, the case of an aide-de-camp, or dragoon, galloping across a plain, at a distance say of 850 yards. Now, we know that our *Enfield* bullet takes three seconds to traverse 850 yards. As a horse will gallop about 500 yards in a minute, that is, 25 yards in three seconds, it follows, that, to cause a simultaneous "meeting" between the bold dragoon and our bullet, it will be necessary to aim exactly 25 yards in front of his horse's head, or about *twelve lengths of the horse* in advance of him: an approximation by no means difficult to a practised eye and steady hand.

Of course it would be absurd to suppose that we are to work out a problem in the rule of three before each shot, when firing at a moving object. If we did so even a tortoise would escape us; and we might, in the mean time, become ourselves food for some of the enemy's sharpshooters. Practice and judgment, as in the case of neutralising the bad effect of wind, are the best guides in this kind of shooting. The deer-stalker, or the chamois-hunter, does not occupy his time with intricate sums before pressing the trigger; nor does the sportsman think twice when a snipe rises near him.

XXI. Nevertheless at long ranges a certain degree of consideration is absolutely necessary before firing, unless you are content to throw away your shot. A man will, no doubt, the more readily decide on the aim he ought to take, if he has treasured up in his mind some such experience of the past as may be gleaned from the following aids, which are for the most part taken from the new French Musketry Instruction for Cavalry.

A foot-soldier gets over, at the quick, about 92 yards

per minute; in the French army about 88 yards. At the double, we get over 150 yards per minute, whilst the modern French soldier professes to do 163 yards in the same time, and even more, in what is called the *pas gymnastique*, or their double. A horse walks over about 433 yards in $4\frac{1}{4}$ minutes, trots over the same in about 2 minutes, and gallops over the distance in about one minute.

In conformity with these approximations the following aids to accurate shooting have been suggested.* First, at a horse *walking* :—

At 108 yards, aim at the horse's *shoulder*.

,, 216 yards, aim at his *nose*.

,, 324 yards, aim about half the length of the horse in advance of his head.

,, 432 yards, aim in advance of his head, one whole length of the horse.

,, 540 yards, aim a length and a half of the horse in advance of his head, or about 9 feet 6 inches.

,, 650 yards, aim two lengths or rather more a-head in like manner.

At a horse *trotting* :—

At 108 yards, aim at the horse's head.

,, 216 yards, aim rather less than his length beyond his head.

,, 324 yards, a length and a half beyond.

,, 540 yards, four lengths beyond.

,, 650 yards, six lengths beyond.

At a horse *galloping* :—

At 108 yards, half the length of the horse beyond.

* The distances in yards correspond to the French measurement in metres; but of course the "round numbers" will be sufficient for our purpose.

At 216 yards, two lengths.
,, 324 yards, four lengths.
,, 432 yards, six lengths.
,, 540 yards, eight lengths.
,, 650 yards, twelve lengths and a half.

These indications must not be considered absolutely correct. They must be taken as general approximations or averages, susceptible of modification, according to the eyesight of each firer, atmospherical circumstances, and the configuration of the landscape.

The lengths of the horses are approximately calculated in the proportion of 2 metres (6 feet 6 inches) as the unit.

XXII. In this kind of shooting, practice more than anything else must obviously be the best guide; and, unfortunately, this is just the thing we cannot have, at least during "the piping times of peace;" however, there is no saying what the future may have in store for us in this matter.

Some time since there appeared in the *Times* newspaper an elaborate letter, suggesting that a railway should be constructed at the School of Musketry, and targets fitted on trucks, so that when set in motion the class going through instruction might have an opportunity of practising at moving objects. This ingenious writer did not, however, volunteer to supply the funds for the construction of the said railway, nor did he offer to be the engine-driver whilst the class carried on their practice at the truck.

It cannot be denied, however, that the ability to hit a distant object moving along at a rapid rate gives evidence of superior skill and judgement; and it may be asked whether it would not be worth while for Government to give soldiers—marksmen for instance—the means of prac-

tising occasionally at objects set in motion by some mechanical appliance? Until such a question is decided, however, we must content ourselves with the chance of getting an occasional shot at the running man or deer established with so much success at Wimbledon. The former represents the figure of a Volunteer "at the double," and the latter is quite a work of art, being a life-size representation of a "running deer," made in iron from a drawing by Sir E. Landseer, and coloured with great fidelity to nature. A plan of the Wimbledon Butt for this purpose is given in fig. 56.

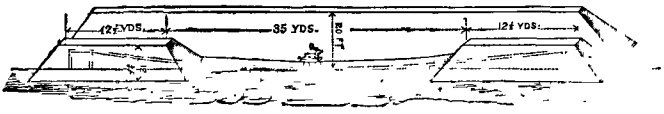


Fig. 56.

This plan of butt is, however, objectionable on the score of expense; it demands a long space of ground; necessitates two markers, and after all involves a considerable lapse of time between each shot. As there is little doubt that firing at the figure of a man, exposed under circumstances as

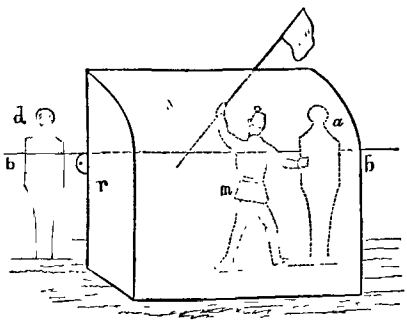


Fig. 57.

nearly as possible resembling those of ordinary warfare,

would be a most useful practice, the arrangement shown in figs. 57 and 58 has been suggested for this purpose,* and at the same time it will be found inexpensive and applicable to our present butts, requiring but one marker, and is also expeditious in its working.

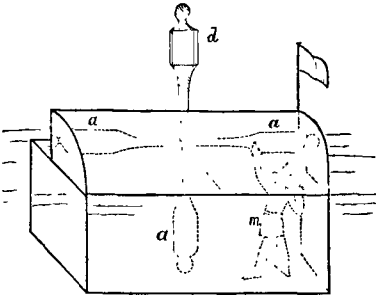


Fig. 58.

Fig. 57 represents the plan as applied to an ordinary mantelet or a ricochet mantelet, and fig. 58 a modification which could be used when there is a pit or sunk mantelet, as in Mr. Hill's system of marking, which will probably become very general, as it is already much approved. In fig. 57 *bb* is a light wooden bar long enough to project three feet beyond each side of the mantelet when placed horizontally on two rollers or wheels, of which one is seen at *r*.

About three feet from each end of the bar is fixed a pasteboard figure (*a* and *d*), cut out to resemble a man five feet six inches in height.

The marker is in the mantelet. Bugle sounds "commence firing." Marker pushes the bar to one side, exposing figure *d* as in the sketch. A shot is fired. Marker moves the bar (which runs easily on the rollers), and brings the "wounded" figure *d* inside the mantelet. He sees where the shot struck, hoists his appropriate flag, and applies a paper patch to the bullet hole. The movement of the bar which brought *d* in will protrude figure *a* beyond the other side of the mantelet, and thus two squads will fire with one marker. The

* The Volunteer Service Gazette.

figure should be kept only fifteen seconds exposed at a time, and a miss reckoned to him who fails to fire within that period. This time will be enough, for there is in each case another fifteen seconds (while the other squad is firing) to come to the "ready." Thus it will be seen that, allowing for numerous delays, two squads of ten each could easily fire five rounds per man an hour.

Fig. 58 represents the plan modified so as to be used in a pit. Here we have four pasteboard men, fixed on light arms, like those of a windmill, and represented separately in fig. 59.

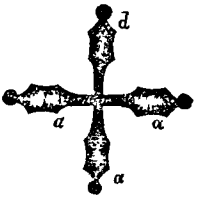


Fig. 59.

The axle carrying these turns in bearings so placed as to allow one "man," *d*, to be exposed above the top of the mantelet, while all the others, represented by dotted lines in fig. 58, are effectually protected below. In this case the marker in the pit simply turns the "mill" one quarter round at a time, and thus brings the "man" just shot down to his own level, when he signals, and then applies a patch, and so on successively. Only one squad would fire at this at once, but the same number of shots could be fired as before. It might save trouble, also, to signal a miss with the flag, and keep the "man" still up until he is hit. That part of each bar which is exposed to fire should be separate from the stronger and permanent part (in both systems), so that, if damaged, it could be at once detached and replaced. Pasteboard has no splinters, and the worn out or "old men" too much riddled for use will sell again almost for their cost, as is the case in the pasteboard targets used at Vincennes.

XXIII. However, all our efforts to secure good shooting will prove but abortive if the cartridge lacks the quantity of powder requisite to drive the bullet home to its destination. The quantity of powder in the cartridge is absolutely necessary to give the proper pitch to the trajectory throughout its entire length. We are apt to imagine that when firing at the short distances a loss of powder is of no consequence. This is a mistake. Without the full charge the velocity of the bullet is diminished, and therefore the trajectory cannot

be such as it is supposed to be in the adjustment of our sights. Thus, a diminished charge neutralizes the efficacy of the sights.

The Enfield rifle is sighted for 2½ drams of the best Government powder; and we may solemnly declare that not a grain of it can be lost without diminishing the flatness of the trajectory. Indeed, a heavier charge would certainly make the trajectory flatter than it is, but then it would also make your pouches heavier than they are, and, besides that, it would increase the kick, and be more apt to strip the bullet.* So be careful—be niggardly of the "precious grains." Your life may actually depend upon a few grains of powder lost in loading, or from an *ill-used*, or, we may add, an *ill-made*, cartridge.

XXIV. Our cartridges are made up in millions by boys at Woolwich,—a little army of some 800 being constantly employed in the operation. The process requires considerable nicety. The case which contains the powder is made

* It was found, with the old smooth-bore musket, that a greater charge than 0·5 of the weight of the ball injured the touch-hole, and yet produced scarcely any greater effect than a charge of that proportion. On the other hand, if the charge were only diminished to 0·4 of the weight of the ball, the effect in shortening the range was trifling, but, if below that, very considerable indeed. If the charge was increased, the recoil was also very great, so that from 0·4 to 0·5 of the weight of the ball was considered the most appropriate charge, and it was adopted in all armies. It was held as a rule, in general, to increase the charge till the gun kicked, and this was always found to be the case with the charge between 0·4 to 0·5 of the weight of the ball. (Müller, "Science of War.") It must be remembered, however, that with a much lighter ball they used nearly three times as much powder as is now used with the rifle. Of course a great portion of the powder was blown out, unburnt, which would not be the case with the rifle. A greater charge would certainly flatten the trajectory, but it would increase the "kick," and might burst the gun if carried much further. See Appendix L.

of paper, being formed from pulp moulded into the required shape; this case has next to be filled with powder—the charge being merely *measured* out and not weighed.

By long practice, some of the boys accomplish the operation in a surprisingly short space of time; however, as "boys will be boys," it sometimes happens that their celerity only affords another example of the saying "more haste, less speed"—as far as the fabrication of a "perfect article" is concerned. This result is, perhaps, one of the "necessary evils" of life, but it really becomes a serious consideration when we reflect on the numerous cases in battle where all may depend upon the proper pitch of the trajectory as affected by the velocity of the bullet, which again depends upon the proper charge of powder. Again, marksmen may be ordered to do some particular "business" at long-range, and it will be a hard case if they get the blame which should properly fall on the "clever boys" at Woolwich. Certain it is, that the speed of the bullet is frequently very much diminished by the fact that the cartridges fail to contain the proper quantity of powder; nay, I have known instances where the cartridge did not contain a single grain of powder! It is said that "Extremes in nature equal ends produce," and that "In man they join to some mysterious use,"* but it is difficult to estimate the "end" or object of an empty cartridge in a soldier's pouch, or the "mysterious use" to which it can be applied. In general, however, the Government cartridges are wonderfully uniform, and, considering their remarkable cheapness, too much praise cannot be awarded to the department by which they are produced.

As loading without powder gives rise to serious inconveniences, and puts a man, for the time being, virtually "hors

* Pope, "Essay on Man."

de combat," and as an insufficient quantity produces inaccurate shooting, the necessity for invariably glancing the eye at the cartridge whilst in the act of loading is obvious. When the charge is insufficient, the soldier must remedy the evil by increasing the elevation of the piece proportionately to the deficieney, to the best of his judgment. A little practice with deficient charges would not, perhaps, be waste of time or powder, since this is a casualty which must be counted upon in war.

In match-shooting, at long ranges, it is notorious that the variation of a very few grains in the weight of either the powder or the bullet makes the difference of a centre or an outer, nay, more frequently, of going under or over a target only 6ft. high, placed at a distance of 1,000 yards from the shooter. Hence, to fire at such matches with any chance of success, it becomes necessary to weigh each charge of powder and every bullet. Nevertheless, when a charge of powder of excessive strength is used, it is the opinion of many good shots that a few grains more or less makes little difference, as there is a limit to the quantity that will actually take fire in the barrel.

XXV. The *condition* of the powder in the cartridge has sometimes much to do with the irregularities in shooting. Moisture is, undoubtedly, the greatest enemy to gunpowder. "Trust in God, and keep your powder dry," said Oliver Cromwell to his sturdy warriors of old; and we may say the same to you. Moisture in the powder causes a diminution in the range, and therefore all possible means must be taken to protect our ammunition. To promote this object, a thorough system of ventilation must be secured wherever our cartridges are kept, so as to enable the air to carry off whatever moisture may be generated.

XXVI. Uniformity in the size of the grain in powder is another important matter; and, to ensure this, Horatio Ross

recommends *scientific* riflemen to purchase a good many pounds of powder and mix them all together, so as to insure uniformity in the strength of the charge.

Some time ago an invention was brought out consisting of a mode of compressing gunpowder in the form of a cake after mixing it with gum and alcohol, without injury, it is said, to the rapidity of combustion; although this seems rather questionable, since granulation is generally supposed to be an essential quality to secure rapidity of combustion. However, should the rapidity of combustion prove to be sufficient, there can be no doubt that in the case of breech-loaders the invention will be invaluable, as it would then be possible to introduce the charge of powder at the breech without the intervention of paper, which forms one of the few remaining objections to the introduction of the breech-loading principle.

XXVII. The cartridge is most probably an Italian invention, as its name implies; for it is really only the vulgar corruption from the French *cartouche*, derived from the Italian *cartoccio*, a word referring to its external material, the paper, which in Low Latin was *charta*, as in our boasted *Magna Charta*. The cartridge-box, or cartouche-box, was invented by Gustavus Adolphus; and the mode of slinging it behind was finally settled, after much discussion, by the French. At first a wooden ramrod was used to load with; the iron ramrod was invented by Frederick the Great.* Originally a powder-horn, or flask, was used for the charge of powder; then they contrived a large leather belt, called a *bandolier*, worn over the shoulder; and to this were hung twelve wooden cases, each containing one charge, with a case of finer powder for priming.† These bandoliers being found very inconvenient, were abandoned

* Steinmetz, in "The Rifle and the Man."

† Colonel Wilford's "Hythe Lectures," or "Class Book."

in France in 1684, the powder-flask was resumed, and the cartridge subsequently invented.

XXVIII. To pour in the charge of powder seems a very simple affair. It is, however, the most important part of loading; and I need not remind you of all the care and exactitude required in this part of Platoon Exercise. If it be too much to expect that, however well trained, soldiers will always perfectly conform to the regulations in this matter, yet there can be no doubt that, if we habituate ourselves to an accurate method of loading beforehand, the habit will last, and serve our turn on the field of battle.

When practicable, we are told, the advantage of loading standing should be inculcated. The term, "when practicable," in this instance, evidently means when consistent with due regard to personal safety. Of course, when a man has a stout oak-tree to stand behind, or a granite wall, or the parapet of a work, he should then load standing, so as to keep the barrel of his rifle upright. The disadvantage of loading with the barrel in any other position is evident, from the fact that after the discharge of the rifle a certain quantity of fouling is always deposited in the barrel. This residue of the exploded gunpowder consists chiefly of a "salt," which is highly deliquescent—that is, it imbibes moisture from the air; and, consequently, when we load in the kneeling position, with the barrel in a slanting direction, after the first discharge, the powder naturally runs down the lower side of the barrel, and a certain quantity adheres, so that not only will a portion of the charge be stopped before reaching its proper destination at the breech, but that very portion will fill up the grooves, clog their action, and render the loading more difficult. Hence the advice, when practicable, in all cases to hold the barrel to the front, and perpendicular, so that every grain of the charge may find its way to the bottom of the barrel, and so

prevent the evils that have been described as resulting from an inexact measurement of the charge, here produced in a different manner.*

XXIX. And here we may observe that one of the many important advantages of a good breech-loader is, that with it the soldier would be able to load in any position effectually, even when lying at full length on the ground. In this prone position the marksman lies down on his chest, his body forming an angle with the line of sight; both elbows rest upon the ground beneath the rifle, the butt of which is pressed into the shoulder immediately beneath the collar bone. For military purposes this "lying position" has the immense advantage of presenting the least possible mark for an enemy; at 500 yards, a small stone, the size of a man's hand, being sufficient to screen a man from view. Moreover, great steadiness is secured from the whole of the body, and both elbows, being solidly supported by the earth, and, from the small surface exposed, wind has little or no effect in disturbing the aim.

Fig. 60.

Fig. 60 represents an illustration of the three modes of

* The French skirmishers always halt to load, and then double up to the line advancing. It is most difficult to load accurately whilst moving, besides the certainty of spilling some of the powder.

loading: Nos. 1 and 2 are supposed to be armed with a muzzle-loader, and loading standing or kneeling; No. 3 represents the front presented by a man loading in a recumbent position, for which purpose the Westley Richards breech-loader is admirably adapted.*

Now, of the three human targets, which would be the easiest to hit?

XXX. The object of wrapping the paper round the bullet is to prevent what is called "leading," or coating the bore with lead. Without the paper this would result from the great friction between the soft lead and hard iron during the passage of the bullet down the bore.

On the other hand, however, the resistance or friction of the paper against the grooved iron, although it might prevent "leading," would obviously have a retarding influence, and lessen the velocity of the bullet. It would be like driving a coach the axles of whose wheels had never been greased; or like shaving without either soap or water. Some kind of lubrication, that is, some material tending to make slippery, is as requisite at the launching, so to speak, of our bullet, as it is at that of a ship from the "slips." A lubricant must be used; for, in this respect, paper is identical with wood.

Now, it so happens, that, of all the many "little things" to be considered in musketry,

Nought more perplexes than the bullet's *grease*—

* Our cavalry have to a certain extent been recently furnished with a beautiful little carbine on this principle. Its trajectory is lower than that of the *Enfield*, and its mode of loading is simplicity itself. Of course the difficulty of loading on horseback has secured this favour for the cavalry; and it is to be hoped that, when all the advantages of the breech-loader become known, it will be given to the whole army, with adequate training to render its use as efficacious as it should be in the hands of taught soldiers.

for this simple reason, that the difficulty meets us everywhere. It may be said literally, as well as metaphorically, that the sun never sets on the army of Great Britain; for it is its proud prerogative to do service in every clime under the sun.

It was no easy matter to find a material that would preserve itself equally well in the depths of an arctic winter, as in the burning summer of the torrid zone.

Tallow did very well as long as it remained tallow; but in India tallow, or indeed grease simple and pure of any kind, melted and vanished long before it had a chance of doing so in the gun-barrel.

In addition to this difficulty there was another disadvantage in the use of grease as a lubricant in a temperature of 70 degrees Fahrenheit. Tallow, or oily or fatty matter of any kind, cannot long be in contact with lead without acting chemically upon the latter,—producing by oxydation a white incrustation round the bullet—the chemical product of the union being nothing less than the very adhesive material known by the medical name of "diachylon plaister;" and the effect of wrapping our bullets in this surgical sticking plaister is more easily imagined than described.

Moreover, the fat of the pig gave dire offence to the superstition of the Sepoys.*

XXXI. Numerous were the suggestions which poured into the War Office on this subject. One man proposed a preparation of caoutchouc, or India-rubber; recommending it on the ground that "it possesses great powers of *adhesion* to any surface to which it may be applied!" Another thought that "glycerine," or sugar of oil, was the only true

* When in India, I actually saw barrels of ammunition labelled "For *European* troops," in contradistinction to others, prepared for the "natives."

panacea; and proposed that "every soldier should carry attached to the side of his pouch a small metal cup or box, containing about 3 ounces of the liquid, so constructed that the mouth, rather larger in diameter than the bore of the rifle, closing with a spring and disc, should permit the cartridge to be 'dipped' half the length of the bullet, the spiral spring forcing the disc back and retaining it in its place, so as to close the orifice immediately the bullet was withdrawn." This inventor forgot the simple fact, that glycerine is made horny or coagulates by a degree of heat far below that which it would encounter in the firing barrel. Such are specimens of the innumerable suggestions, much more ingenious than well-considered, to meet the difficulty. At length, however, when "hope had well nigh given way to despair," Captain Boxer of the Royal Artillery, in a happy moment, bethought himself of the material with which the little busy bee builds a store-house warranted to keep in all temperatures and climates, namely, bees'-wax, which was added to fat in the proportion of five parts of the former to one of the latter.*

XXXII. It was, however, alleged, that in Indian service, after a number of shots, the rifle becomes useless owing to the clogging effect of the bees'-wax; but it seems doubtful whether the result was produced in the manner supposed,—the probable cause, as suggested by Mr. W. Bridges Adams, being perhaps rather the fact that iron is easily acted on by acids, and that acids are produced in the barrel by the combustion of the sulphur and nitre—and, therefore, these deposits should be wiped out as they are produced. The tired soldier neglects to do this, and throws himself down on the ground to sleep by the side of his fouled gun, after a hard-fought day; and on the following

* The French proportions are four parts of fat to one of wax.

morning the interior of the barrel has become rusted—presenting, in fact, a roughened surface like that of a file. What is the consequence? The leaden bullet, expanded by the discharge, soon imparts a leaden skin, as it were, to the bore, just as every workman knows that a file will get clogged in cutting lead. Every subsequent shot fired only tends to add to this coating of lead, so that a point is reached when loading with ball becomes impossible. As a matter of fact illustrative of this, we may state, that, after the Crimean war, Enfield rifles were found with the cylindrical remains of *seven* bullets in one barrel! As long, then, as iron is thus constituted—so susceptible of the action of rust by moisture and acids—the difficulty can only be surmounted by the soldier being supplied with a ready means of giving to the inside of his barrel a smooth polished surface, its proper condition.

This means is now furnished to the soldier by order of the Commander in Chief, free of all expense to himself, in the shape of gun-oil, with an adequate quantity of rag; and these are henceforth to form as essential a part of military stores, either at home or abroad, in peace or war, as gunpowder or lead.*

It would appear, however, from subsequent investigations, that the difficulty in loading was really caused by retaining tallow in the lubricant, even in the small proportion mentioned; for it was found that the diameter of the bullet became

* All oils necessarily contain water, or the gases that form it, and therefore they should be boiled, so as to drive off its excess as much as possible. The oil issued by the Government is Rangoon earth-oil, a natural product collected in very large quantities in the neighbourhood of Rangoon in British India. It seems to have been discovered by some of the British officers after the late Burmese War. It arrives in this country with about the consistency of tar, and nearly of the same colour. By distillation and other processes it produces

perceptibly enlarged from the white deposit resulting from the chemical action already explained. Hence, in 1859, tallow was dispensed with, and bees' wax, pure and simple, substituted. The advisability of this decision has recently been endorsed by the Small Arms Committee, who declare emphatically that the lubricant best adapted for all climates and conditions is pure bees' wax.

XXXIII. The absolute necessity for a lubricant of some kind for our bullet having been explained, it becomes a question what is to be done should our "lubricating mixture" or material have become removed by evaporation and absorption; or, as happens perhaps most frequently, should dirt and impalpable dust have so united with it as to nullify its action? In such a case what is the soldier to do? The advice given by the Red Book is simply that the soldier should then wet the sides of the bullet in his mouth, and the saliva will serve the purpose of grease for the time. This advice may not seem very savoury, but, depend upon it, it is salutary. Necessity has no law; and it will not do for the rifleman in the field to be too particular and fastidious. When at Wimbledon in 1860, I used to observe the Swiss competitors, when loading, extract a linen patch from a side pocket and put it in their mouth, where they would roll it round and round, like a sweet morsel on the

a burning oil or spirit of light specific gravity (parafine), also a heavy oil for lubricating purposes, now adopted by the Government for the rifle. Its properties are great limpidity and thinness, or just sufficient oleaginous nature and no more to prevent the accumulation of dirt,—and its small liability to get thick or solidified as other oils at low temperatures. It is found also to answer well for machinery.

The well-known parafine candles, quite equal to spermaceti, are also manufactured from this curious mineral oil; and even its refuse is utilised for commercial purposes.

tongue, much as a sailor gustates his quid of tobacco—with the view of thoroughly saturating the patch with saliva before wrapping it round the bullet; and thus they gave a ready solution to the lubrication difficulty. Again, I have read somewhere of a Rifle Corps in one of the German States, the members of which carry small flasks of water, from which they pour out some drops to moisten and distend the linen patch in which they envelope their bullet before loading; and probably this beneficially affects their shooting, otherwise the custom would not be retained.

XXXIV. In the preceding investigations we have had to consider not a few causes of inaccurate firing; but there still remains a fatal one—for which there is no remedy on the part of the firer—"the rifle may not have a proper bore." All our attention to obviate the causes of inaccurate firing will be useless if the gunsmith has not done his duty on the weapon placed in our hands for the service of our Queen and country.

The essential condition of a rifle is accuracy in the construction of the barrel: the rifle-bore must be "true."

Man's handiwork is at all times short of perfection, and, moreover, the work of one man differs materially in point of excellence from that of another. In spite of our claim to be a nation possessing the most skilful mechanics in the world, it may be questioned whether the bore of any two rifles is exactly similar. Of late years some curious facts have come to light. For instance, it is stated that the best Birmingham manufacturers have never approached nearer to accuracy in the bore of the piece than the 350th of an inch,—a degree of accuracy sufficiently startling when we endeavour to "realize" that minute fraction of an inch; but we are assured that Mr. Whitworth, in the hexagonal

bore of his rifle, has positively attained an accuracy up to the 5000th of an inch—one of those astounding facts of art as difficult to prove to the senses as anything that we deem mysterious or miraculous.

XXXV. As, already explained, the rifle-barrel should be perfectly cylindrical in the bore; we can generally discover when it is not so in the act of pressing the bullet "home." Should the bullet invariably stick in the same spot, and, on being *forced* past that point, drop freely—quicker than the rod can follow it—then it clearly indicates some imperfection in the bore; perhaps, however, more frequently traceable to the owner than the maker of the weapon. Perhaps the barrel has received a blow, or has been used to carry some weight, and has thus become indented. Such a state of the case may be represented, of course in an exaggerated form, in the following figure:

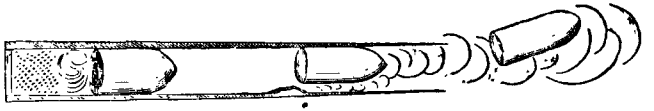


Fig. 61.

In any such condition of the bore the accuracy of the fire must be much impaired. The bullet being expanded by the gaseous force behind and the resisting air in front, passes along the grooves until it meets this indentation, where, should it not burst the gun, it must, as it were, accommodate itself to the circumstances by narrowing itself so as to effect a passage. Unfortunately, however, no further expansion of the bullet can take place; and the consequence is that during the rest of its course down the tube, instead of conforming to the axis of the piece—its true direction, it adopts a zig-zag motion, owing in a great measure to the force of the gas, which, travelling

in the tube at a rate of something like 7,000 feet per second, rushes past the bullet before it has quitted the muzzle, shaking it to and fro like a pea in a bladder, and causing it, at last, to quit the muzzle at an angle utterly at variance with accurate shooting.

XXXVI. Much the same result ensues should the muzzle of the gun become what is termed "freed," or bell-shaped, in however partial a degree. As soon as the bullet reaches the enlarged orifice of the gun the gas rushes out past the bullet, and thus causes it to turn over and rotate in an irregular manner, utterly destructive of good shooting. Colonel Wilford had a favourite Enfield rifle which began to fail in its shooting, the muzzle having become slightly enlarged. He made the armourer saw off an inch from the end of it, when its shooting capabilities were decidedly improved; and I can testify that with this rifle, thus amended, he made many a bull's-eye. Perhaps since then he has had to amputate another slice from the muzzle; but such a method of cure must obviously have a limit, as "you can't eat your cake and have it;" in fact it is, like the surgical operation for cancer, in which one may go on lopping off as long as life lasts without getting to the end of the malady.

In either of the cases mentioned an immediate report should be made, with the view of having the barrel inspected officially, by what may be termed the application of the "test act." Any flaw of the kind can be at once detected by means of two steel plugs, called the "receiver" and the "rejector." The diameter of the "receiving" plug is ·577, and when screwed to the end of a ramrod, and lubricated with a little oil, it should pass smoothly and evenly down to the bottom of the barrel. The "rejecting" plug has a diameter of ·580, that is ·003 more than the barrel; and should, as its name implies, refuse to enter the

barrel however slightly. But it may enter a barrel which has become slightly "freed" at the muzzle for one or two inches. If, however, it has access beyond that distance, it is destructive of good shooting. A set of these plugs should be at hand in every regiment or rifle corps; for it is satisfactory for a man to know whether he has himself or his gun to blame for his bad shooting. Moreover, their use may be the means of preventing accident in the shape of the bursting of the barrel.

XXXVII. Some of the matters which we have investigated in connection with the practice of shooting, when considered separately, may appear trifling and of small consequence, but taken collectively due regard to them tends materially to the formation of a good rifle-shot. In truth, good shooting is only to be acquired by attending to a number of *small* things. For, when we come to anything like long-range shooting, even the slightest defect, what at shorter ranges was considered the veriest trifle, becomes magnified and increased in importance to a serious extent. No one who has any ambition to become a first-class rifle-shot can afford to disregard these hints, and the greater the consideration he gives to them the more certain will be his reward.

APPENDIX K.

By the refraction of light a fish in the water, seen obliquely from the land, appears nearer the surface of the water than it actually is, and somewhat in advance of the position it really occupies; a marksman shooting at it must therefore aim below the place which it seems to occupy.

The celebrated "Pepper's Ghost," of the Polytechnic, is another illustration of the phenomenon which is presented in the desert mirage—a large plate of glass, imperceptible to the benighted audience, being the reflecting medium.

In front of the stage is a large plate of glass hanging on hinges allowing it to be sloped at any angle. A powerful light below the front of the stage is thrown upon the suspended skeleton or other figure whose ghostly appearance is required, and the image or "ghost" is reflected from the glass,—but, the rays being reflected as in a looking-glass, the image is apparently thrown beyond and upon the stage—the motion of rising being given to it by sloping the glass-plate still further. Such is the very simple "mystery" of the whole affair. Of course the image is visible only to the spectators in front; the performers see nothing of it. This very clever contrivance was positively suggested by a fact of every-day occurrence and experience. If you look into any shop-window, or indeed through any glass-window, with the light shining in front of you, you will see your image beyond the glass—more or less distinct according to the obscurity of the background and the intensity of the light beaming upon your person. Indeed, the invention was suggested by the image of the passengers in an omnibus, projected beyond the glass-panes. Mr. Pepper has certainly developed this "mirage" into a real Golconda of sterling profit. The knowledge of the secret positively enhances the startling effect of the exhibition.

A spectator could "shoot the ghost" by simply smashing the sheet of plate-glass which intervenes between him and the stage; whereas any one on the stage may fire or thrust at the phantom figure without in any way discomposing its spirit-like serenity.

APPENDIX L.

The bursting of a gun depends upon the maximum tension of the gas of the gunpowder. The tension of this gas increases very rapidly, and very soon reaches its maximum. Suppose this maximum is attained when the projectile is displaced to the extent of half a calibre,—it is evident that the space occupied by the gas is smaller in the gun with a smaller calibre, and consequently the density of the

gas is greater. As the tension of this gas increases in proportion to its density, it follows that the maximum effort of the elastic fluid will be much greater in a gun whose bore has a smaller diameter. The same conclusion follows if, instead of supposing the point corresponding to the maximum of tension at the same fraction of the calibre, we take it as at an equal distance in the two guns compared. Whatever may be the value of this explanation, it is certain that a great many rifled guns have burst in the experiments carried on in various countries; and a list of such accidents is given by Saint-Robert, who invites the attention of artillerists to this paradoxical fact, which should be verified. The burstings which he enumerates prove that the increase of the charge of powder in rifled cannon—to flatten the trajectory—is not without danger. Perhaps the difficulty might be met by a different metal in the gun, steel for instance, or aluminium-bronze. It is certain, however, that the defect in question is less in rifles than in rifled cannon, because we can endow the former with a greater comparative resistance.—SAINT ROBERT, *Considerations sur le Tir des Armes à Feu rayées.*

LECTURE VII.

[Seventh Lesson, Red Book, page 30.]

Causes of uncertain fire in the smooth-bore musket—Excess of Windage—Error due to excess of windage rectified by the expanding ball—Error due to a defective figure—The PROJECTILE.

I. A state of disease demands a physician; and never was such a necessity more imperative than in the case of our old friend "Brown Bess," who, in her day, has had so many "followers" and "admirers"—from the Duke of Wellington down to the drummer boy—that even now, in 1863, some remain who believe in the "soundness" of her condition, and fail utterly to perceive that her system was radically bad. In plain words, owing to certain mechanical defects in the construction and arrangement of the weapon, it could not shoot; or, at most,—it could merely project a ball with a certain degree of accuracy about as far as a man of ordinary strength could throw a stone—the width of a good-sized London street!

II. When we consider that this weapon had been the constant companion of its admirers throughout the campaigns of the old wars, terminating so gloriously for England, perhaps we ought not to feel surprised to find them slow to believe in its inefficacy as a military arm; and the more so, because during a period such as the 18th century, when all battles were fought and won by the rapid firing of deployed lines at close quarters, its large charge, heavy ball, and rapid fire at these short distances, had, undoubtedly, often rolled back the tide of war, and carried our colours triumphantly

through India, Egypt, the Peninsula, and the final struggle of Waterloo.

III. In endeavouring, however, to arrive at a correct estimate of this weapon, we must guard ourselves against being biassed by mere sentiment, connected with its past history. In determining the comparative merits of a fire-arm, we must take only trustworthy accounts of its performance and specific facts into consideration. Here, then, are some of the facts we wish to adduce for and against "Brown Bess," by way of preface to the present lecture.

It must be admitted that, at close quarters, Brown Bess had a flat and raking trajectory, owing to the tremendous velocity of the ball, caused by the enormous charge of powder; from its immense amount of windage it loaded easily; and, although rather too heavy for long marches, it was strong enough to bear any amount of hard usage.*

But what were the general results of firing with the smooth-bores of old? During the wars of the French Revolution and the Empire, according to Gassendi, a French general, in his time the oracle of artillery, the infantry fired 3,000 cartridges for every enemy killed or wounded. Piobert, the authority of the present day, admits the same fact. Decker, a Prussian general, and one of the best military authorities of Germany, estimates that not less than 10,000 cartridges are burnt for every enemy killed or wounded; and Guilbert, another high authority, calculated that, in the

* Perhaps the following estimate hits off the point completely:—

All that the soldier then design'd
Was rapid firing in a space confin'd;—
Not *aim* the care, but *time* to load employ'd—
As flamed his lawless bullets thro' the void.
He'd miss a man—but hardly could he miss
A troop—or *haystack*, as the saying is.

STEINMETZ, *The Rifle and the Man.*

battles of old, it required a *million* of cartridges to kill 200 men in battle. At Vittoria, 21 June, 1813, the Allies numbered 50,000, the enemy 90,000, of whom there were killed and wounded 8,000. The Allies fired 3,675,000 shots; the effective shots were, therefore, only 1 in 800; much better firing, however, than usual in the continental armies of the time. It is stated that, at the Cape of Good Hope, after our troops had fired 80,000 rounds, only 25 Caffres were killed; being in the proportion of 1 Caffre for 3,200 rounds !* In the Crimea, the French, who were almost entirely armed with the smooth-bore, fired away 25,000,000 cartridges, and it is not even imagined that they hit 25,000 Russians.

The weapon was, moreover, subjected to a practical test as to its accuracy, which, it seems, had been taken for granted in spite of the results of battle-fields. Soon after the Battle of Waterloo, the Prince Regent, afterwards George IV., imagining that the French cuirasse was sufficiently strong to ward off blows and bullets, thought of introducing it into our service; so, with the view of testing its invulnerability, he had one sent down to Woolwich to be experimented on by the balls of *Brown Bess*, at a distance of 200 yards. The cuirass was accordingly mounted on a pole, the gun was screwed in a vice, and every other means taken which was thought likely to secure success in the experiment. Unfortunately, however, they could not get the gun to *hit* the cuirass, until, at last, a random shot, fired by a Captain Miller, R.E., did take effect.

Still more remarkable facts bear evidence on this subject. According to the evidence of a body of officers of the Royal Engineer Corps, who were employed some years back to ascertain the actual capabilities of the old regulation smooth-bore,

* This does not apply to the war in 1851.

we find, first, that, as to the range of the weapon, nothing more certain could be discovered than that it would carry 100 or 700 yards, according to the elevation given; but at no degree of elevation was there a less variation than 100 yards; and at some elevations this difference in the distance it carried amounted to 300 yards. On the point of accuracy, the revelations were still more astounding. At a distance of 150 yards, a target about twice as high and twice as broad as a man could, with very careful shooting, be hit three times out of four. Beyond that distance, notwithstanding that the musket was fired from a stand, and every precaution taken to ensure steadiness and success, the results were *nil*. Nothing could be learnt at all except that the target was never hit, and the balls could never be found. The target was twice as wide as before, but, of ten shots at 250 yards, not one struck, and when the distance was increased to 300 yards it became clear that the firing might just as well have been directed at the moon. Hence Colonel Wilford used to assert that he would sit opposite a man armed with Brown Bess at that distance, and allow him to shoot at him "from morn to dewy eve," provided he always took a *correct aim* at him. In fact it took the weight of a man in lead to kill him in battle, that is to say, so many bullets would have been expended before one could hit him by chance. One more fact will suffice to complete the summary. In a manual or guide-book for the British marksman, founded on the preceding facts, the soldier was directed, when firing at the enemy 600 yards off, to aim 130 feet above him.

Upon the whole, so far as we can make out from the figures before us, it seems that if a soldier, armed with the old fire-lock, were placed at the bottom of Ludgate Hill, the chances would be about 500 to 1 against his hitting St.

Paul's cathedral; and the probability of a man so armed hitting another 500 yards off would be in the ratio of *one farthing* to the National Debt, £800,000,000!

IV. Everybody indeed has long been aware that fire-arms, especially for the purposes of war, were imperfect in the extreme. It has been asserted by the advocates of the smooth-bore system, that the rifle has, in this respect, proved itself to be practically not a whit superior; but this is at variance with facts. At the battle of Chiarumbusco, in Mexico, the Americans, for the most part armed with rifles, killed or wounded a Mexican for every 120 rounds. At the Battle of the Alma, the Allies numbered 40,000 men, the enemy about the same. The enemy lost 8,000, killed and wounded; the Allies fired 1,000,000 rounds, giving 1 in 125 as the result of the rifle in an engagement which lasted only three hours. At Inkerman, the Allies were 16,000 men, the enemy 60,000. The enemy's killed and wounded were 15,000; those of the Allies, 3,000. The Russians fired 4,500,000 rounds; the Allies 1,200,000. Of the Russian shots—from *smooth-bores*, only 1 in 1,500 took effect,—whilst the rifles of the Allies give 1 in 80! The Russians fairly attributed their reverses in part to the superior musketry-fire of the Allies, according to Brabazon, in his "Soldiers and their Science." This writer also adduces two other instances of the superiority of fire resulting from the rifle, namely, the Battle of Ilstedt and the Siege of Rome.

Again, it has been truthfully averred, that, had it not been for the superiority of the fire of the *Enfield*, the Indian mutiny might even now have been unsuppressed,—the rebels being armed, fortunately, with smooth-bores.

Thus, from all the data under consideration, it seems that the average hitting capability of the smooth-bore may be

roughly stated to have been one man for every 3,416 rounds, whereas that of the rifle has hitherto been as 1 to 110.

V. These various estimates are, doubtless, more or less inaccurate; but they nevertheless prove that the fire of infantry, armed with smooth-bore muskets, is far more inaccurate than was generally supposed; and we are thus naturally led to inquire into the causes which produced this marked inferiority in the smooth-bore gun, and the means ultimately adopted for its effectual improvement. In doing so we shall endeavour to trace the defects to their first source, by examining the conditions under which the musket-ball receives the first shock of the exploded gunpowder, and the results that follow from that instant to the end of the range of the projectile.

If the diameter of the ball were exactly the same as that of the bore of the musket-barrel, the friction that the points of contact in the circle would experience would be the same above as below and all round; and, as the force of the powder, on its explosion, would act equally upon every part of the posterior hemisphere or hinder half of the bullet, then, when the bullet was set in motion by the action of the gunpowder, it would move onwards with a simple motion of translation in the direction of the axis of the piece and its continuation, the line of fire; and thus, provided the ball were a perfect sphere and homogeneous throughout, the resistance of the air would be spread equally over its front or anterior surface, and have no other effect than that of retarding its progress or shortening its range, without in any way diverting it from the plane of fire or original direction. In practice, however, and as we shall show in the sequel, it is impossible that these conditions can ever exist or be maintained; for the necessity of loading

easily, and of being able to do so after continuous firing has fouled the barrel, involves the necessity of having a certain difference between the diameter of the ball and the bore of the barrel. This difference is called "windage." The direct consequence of windage is, that, when the musket is held horizontally at the present, the ball naturally rests on the lower surface of the bore, so that the windage is, at the moment of discharge, above the ball.

Now, the gas generated by the gunpowder, when in the barrel, is endowed with a velocity of transmission equal to 7,000 feet per second, and at that rate it at once precipitates itself through the space between the ball and the bore. The ball thus driven against the bottom of the bore rebounds, so that when it is impelled forward by the charge it strikes the upper surface of the bore. This impact again sends the ball against the lower side, where a new shock is produced, with a constant tendency to rebound in a similar manner throughout its passage in the bore; so that, instead of passing out of the barrel evenly along the lower side, the ball advances by a succession of rebounds, until it reaches the muzzle, which it leaves with the accidental direction indicated by C (fig. 62), exactly opposite to that in which it made its last impact. Thus, before quitting the barrel the bullet becomes deflected from the line of fire (represented by the arrow, fig. 62), and has, besides, lost much of

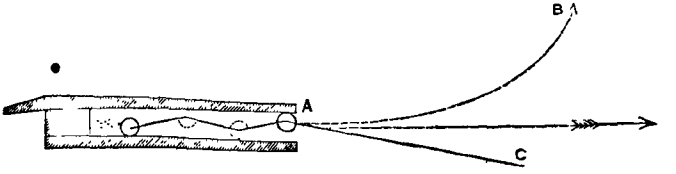


Fig. 62.

its velocity by its frequent impacts in the tube, by the

diminished force of propulsion owing to the escape of the gas, and, rotating like a top after the last impact in the bore, emerges as shown at B in the figure.

VI. Another cause of deviation in the ball of the smooth-bore musket resulted from the amount of friction between the bore and the projectile consequent on the excessive windage. The last impact, as previously observed, produces a rotation in the ball similar to that of a top which spins in obedience to the last friction of the string. "Almost all bullets," says Robins, the first discoverer of the capabilities of the rifle, "receive a whirling motion by rubbing against the sides of the pieces they are discharged from; and this whirling motion of the bullet occasions it to strike the air obliquely to the track of the bullet, and, consequently, deflects it from its course." See fig. 63.

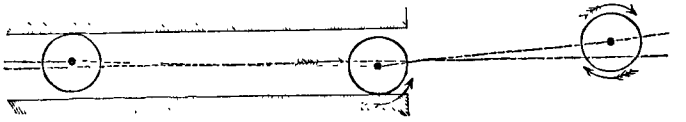


Fig. 63.

Robins showed this by three practical demonstrations or experiments:—1, with a ball and double string; 2, by firing through screens; 3, by firing with a barrel whose muzzle was bent.

The whole of these experiments only proved what is known to every billiard-player—that, if the ball receives a rotation in a certain direction, it will have a bias or tendency to move off towards that direction (fig. 63). Thus, like Roberts or Kentfield, the great billiard players, Brown Bess was constantly giving "side" to her ball, and the motion of the ball, on leaving the muzzle, was of a compound nature, and, consequently, the ball moved in a doubly incurvated track, as shown in fig. 63.

Such were the inconvenience and inaccuracy resulting from excessive windage.

VII. Many were the expedients used to get rid of the necessity of windage, but it almost constantly happened in the efforts to do so that the celerity of firing was greatly diminished. Now, it need hardly be mentioned that one of the most essential conditions of a military fire-arm is, that it must combine *celerity* with accuracy of fire. Perhaps it will not be useless to glance at some of the contrivances from time to time resorted to in order to remedy the inconveniences arising from this excessive windage. The Earl of Orrery, in the middle of the 17th century, mentions that in his time a large proportion of the shot in action rolled out of the barrel before firing, so great was the windage; and that, in order somewhat to neutralise the consequent waste of fire, the soldiers were ordered to ram grass or tow into their barrels; pepper-corns and grains of coarse powder were also used to wedge the bullet into the barrel. Another ancient writer intimates that all *good* musketeers, arquebusiers, &c. should thrust down paper or something equivalent on the ball to prevent it rolling out;* and many other expedients were subsequently resorted to in order to counteract this radical defect.

Another method tried was by loading at the breech; giving to the bore, at or near the breech, a diameter slightly greater (fig. 64) than the other part of the barrel.

* There is a quotation from Williams' "Discourses of Warre" on this point: "But here it may be demanded, what I doo call the well charging of pieces of weapons of fire? Whereunto I answer, that I doo allow neither harquebuze nor mosquet for well charged in services of the fielde, unless they bee charged with conuenient charges of powder, and with soft brown paper, or the refuge ends of matches, or something else, to restrain the same, and likewise vppon the bullet the like or more quantitie to keep close and restrain the bullet."

A shot somewhat larger than the bore could then be placed, together with the charge, in the breech; and, on

Fig. 64.

being pushed forward by the explosion, would press or force itself through the bore, entirely filling it, and excluding the possibility of windage. But, unfortunately, it was impossible in those days, owing to the comparatively rude state of mechanical manufacture, to make the parts sufficiently solid to resist the explosion, and, at the same time, so closely fitted as to prevent an escape of gas. This escape was found to be so great that the method described was soon given up.

VIII. In the Peninsula our troops were, at one time, furnished with two sizes of balls; one large and tight-fitting, for "accurate" shooting at considerable distances; the other much smaller, for quick firing at close quarters. A canvas patch was used in some armies, which, being rammed home with the bullet, was then distended in the barrel by means of a few drops of water let fall upon it from a flask carried for the purpose. Then, for a considerable time, the usual method of loading was as follows. The powder was poured in as usual, the bullet was placed on a patch of greased cloth stretched across the muzzle; with a mallet the ball was then struck until level with the muzzle, and then the handle of the mallet was thrust down into the barrel as far as it would go. The soldier then grasped the ramrod with both hands, and with many a cruel blow and thwack the ball was at length got down. This manner

of loading completely deformed the fore part of the ball, and slightly increased its length, at the same time rendering the process of loading very slow. It is evident that none of the preceding methods of loading fulfilled the conditions required in an arm for soldiers.

IX. To drop a projectile loosely into the barrel, tightening it when there,—that was the problem to be solved; and by a person new to the subject, and ignorant of the manner in which it has been solved, some such idea as the following might be suggested to meet the difficulty. If you take a beer-pot, and an apple dumpling a little smaller than the pot, you may drop the dumpling to the bottom of it. When there you may give it a squeeze, by which it will be flattened, and pressed against the sides in such a way that you may invert the pot, and then the dumpling would not drop out.

The French are remarkable for starting new ideas in matters military; and a French officer, Captain Delvigne of the Garde Royale, in 1828, first attempted to effect this expansion of the bullet.

The problem was, to expand a leaden ball whilst lying on the top of some three or four drachms of gunpowder. As long as the expansion was obtained by mere hammering it was evident that the ordinary breech-pin, with the powder entirely covering its face to a depth of more than an inch, would not afford the necessary resistance for the purpose in view. Hence, after some slight modifications, suggested by experiment, Delvigne proposed a ledge of iron at the proper distance from the face of the breech-pin, on which the ball would rest, instead of lying on

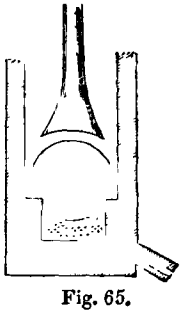


Fig. 65.

the powder (fig. 65); so that, on being struck with a smart blow of the ramrod, the ball might be expanded to a certain extent, and with little difficulty, compared to the old forcing method with its mallet and heavy rod. At the same time this chamber-system had the advantage of protecting the grains of powder from being mealed or bruised.

X. Although the results obtained fully proved the correctness of the principle,* there were many reasons of a military nature for condemning this system of compressing the bullet against the new breech. In the first place the breech fouled rapidly, owing to its contraction; for, after repeated firing, a residuum collected, which eventually left the powder less room in the chamber, thus forcing it above the shoulder of the latter, so that the ball, resting upon the powder instead of the shoulder of the chamber, was not so readily dilated by the stroke of the ramrod; and, secondly, the projectile, as shown in the figure, was not supported in the middle, where it could get the proper benefit of the strokes of the ramrod for expansion, as designed; and the result was, that the soft lead was forced by the ramrod—especially when anything like hard ramming was used—into the chamber, making a boss in the ball, and so lengthening it that its centre of gravity was thrown out, and it turned over in the air, whereby its accuracy was affected. Thus, in some respects, this system substituted a greater inconvenience for a less.

XI. An attempt to remedy these evils was made by Colonel De Poncharra, in 1833, by means of a wooden *sabot*, or clog, which was hollowed out spherically on its upper side, whilst a patch of greased serge was attached round its lower part. This sabot, resting on the shoulder

* The accuracy in shooting at 600 yards was double that of the smooth-bore musket at 350 yards.

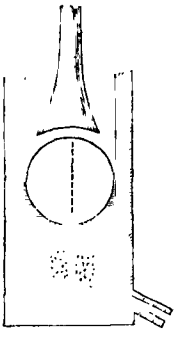


Fig. 66.

of the chamber, gave a fixed support to the ball, thus rendering its lateral expansion more regular and uniform (fig. 66), whilst the grease on the patch, melted by the inflammation of the powder, much facilitated the subsequent loading.

However, the system represented by this Delvigne-Poncharra expansion was attended, in practice, with many inconveniences; and the complicated nature of the ammunition was, of itself, a great and fatal objection in a military arm.

XII. It remained for another French officer, Colonel Thouvenin, to endeavour to improve on Delvigne's idea; and this he did by removing the chamber, and carrying the uniform bore of the piece down as before to the face of the breech-pin, in the centre of which, however, he fixed a short steel stem or pin, which projected into the bore in a line coincident with the axis of the piece, so that the charge of powder was distributed round this stem, the top of which served to arrest the bullet, and thus acted as an anvil, against which the ball could be struck and compressed by the ramrod, to give it the required degree of lateral expansion. Thus the expansion of the ball was rendered more certain and uniform than before, and a greater margin for windage was allowable.

The general results obtained from it were so far satisfactory that it was introduced into the French and other services, under the name of *Carabine à Tige*, and under that name it is still retained by many of the German States.

The *tige* or stem-principle presents many defects, and they may be summed up briefly as resulting—1, from much

fouling round the pillar or stem, which, owing to the difficulty of clearing, requires the soldier to carry an instrument for the purpose ; 2, the *tige*, however well-tempered at first, becomes soft and pliant, owing to its exposure to the heat of the explosion, and ceases to be so effective; 3, it takes up too much space, elongating the charge and placing it at a mechanical disadvantage in its ignition; and, lastly, the ball has still the same tendency to lose its spherical form as in the former expedients already described.

XIII. Hitherto this "carbine with a stem" had only been tried with the old spherical ball; but Delvigne, who had been experimenting in the matter for many years, at length thought of trying an *elongated* bullet—cylindro-conical—with the same weapon (fig. 67); and the results were such that it seemed evident the reign of small-arm spherical projectiles had come to an end.

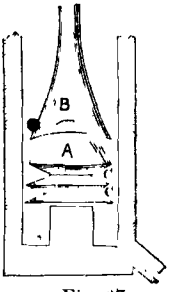


Fig. 67.

The Delvigne bullet, A, had two deep *cannelures*, or channels, C C, so that when the conical head of the bullet was pressed at B by a ramrod, made for the purpose, against the *tige* D, the cannelures collapsed, and the cylindrical portion of the bullet became expanded laterally, so as to fill the barrel.

XIV. An impression had for years been gaining ground that the paramount desideratum of accuracy and celerity in one and the same arm was only to be acquired by a radical change in the form of the projectile; and it does indeed appear strange that the spherical ball, to which it was impossible to impart a principle of self-expansion when in the barrel (although as a first idea for a projectile the sphere was certainly a clever one — presenting the least surface

in a given mass), should have been for a moment retained in working out the problem of expansion.

XV. In the year 1823, Captain Norton, in our own service, came forward with an elongated projectile, and showed the importance of giving that shape to all projectiles. It seems that the idea occurred to him from an examination of the arrow used by the natives of Southern India with their blow-tube. In propelling this arrow by the force of the breath, which they can do in calm weather to the distance of 70 yards, the fine elastic lotus-pith forming its base expands and fills the tube, preventing the loss of force by windage. Following up the idea suggested by this curious fact, Captain Norton, in 1824, perfected a bullet precisely on the principle of the modern self-expanding projectile, and submitted it to the Select Committee on Fire-Arms, then sitting at Woolwich; but this committee, apparently with culpable short-sightedness, refused to entertain the proposal, alleging, amongst other frivolous reasons, although perhaps excusable at that early period of the question, that a "*spherical* ball was the only shape of projectile adapted for military purposes."

Again in 1836 a Mr. Greener invented and submitted for trial at Tynemouth, under the authority of the Master-General and Board of Ordnance, a bullet to expand by the action of the powder: it was somewhat like an egg, having an opening at one end to receive a "taper plug, with a head like a round-topped button, of a composition of lead, tin, and zinc." This plug, which was larger near the head than the opening, was driven home on the explosion of the powder, when the sides were dilated, and forced into the grooves of the rifle, thereby stopping all

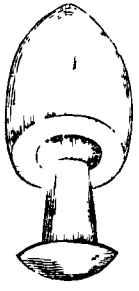


Fig. 68.

windage, and increasing the accuracy of shooting as compared with the government bullet. The Board of Ordnance rejected this invention on the ground of the bullet being a compound one.

It must ever be regretted that the authorities blindly rejected those inventions, either from a want of discernment or through prejudice, and thus deprived England of the honour of having initiated the greatest improvement in small-arms.

But, as Sir William Armstrong has recently happily expressed it, "As in the vegetable kingdom fit conditions of soil and climate quickly cause the appearance of suitable plants, so in the intellectual world fitness of time and circumstances promptly calls forth appropriate devices." The seeds of invention exist as it were in the air, ready to germinate whenever suitable conditions arise, and so, although the germs of this invention appear to have been twice crushed out in England, the seed presently found in France a more genial soil to spring up in, for, during the experiments and investigations consequent upon the adoption of the elongated projectile, in 1841, Delvigne made that discovery which has entirely revolutionised the whole system of fire-arms. With the two-fold object of, first, reducing the weight of his elongated bullet to something like that of the old smooth-bore; and, secondly, in order to throw forward the centre of gravity (as suggested by Robins in his egg-shaped projectile, *vide* fig. 68), he found it advisable to hollow or scoop out the base of his bullet, when it at once became apparent that on the sudden development of the vast body of gas from the powder, it rushes into the hollow or cavity at the base of the bullet, so as to drive or force outwards the side-walls of this thimble-like vault, and cause the bullet so to expand as

to fit the barrel exactly, and do away with all windage. Captain Delvigne himself communicated the result of his researches in these words :—"During these investigations I made an important discovery, which was, that the gas produced by the ignition of the powder, rushing into the cavity formed at the base of the bullet, expanded it." Thus was this important method of obtaining expansion discovered by accident, and was the result of an expedient adopted for a very different purpose.

In this manner Delvigne was enabled to give a practical and definite solution to the difficulty which had so long existed.

Delvigne's discovery was taken up by Captain Minié, who at once abolished the stem or *tige* on the breech-pin, as being no longer requisite ; and he introduced a cup-shaped iron plug (*culot*) into the hollow of the bullet, with the view of increasing expansion, and preventing the gas from passing through the lead (fig. 69), an accident previously of constant occurrence when the solid portion of the bullet was not of sufficient thickness to resist its violence.

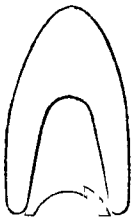


Fig. 69.

XVI. Captain Tamissier, of the French army, afterwards introduced grooves, the twenty-eighth of an inch deep, round the posterior part of the bullet, and he demonstrated the fact that the grooves around the cylindrical part of the bullet have an effect analogous to the feather upon the arrow. His bullets had nine grooves round the cylinder ; and he attained great accuracy at 1,100 yards.

His argument was that the resistance of the air acting upon these grooves behind the centre of gravity of the bullet will tend to bring down its point upon the curve of the trajectory should it be above ; or, if the point falls

below this curve, the resistance acting upwards will tend to raise the point.

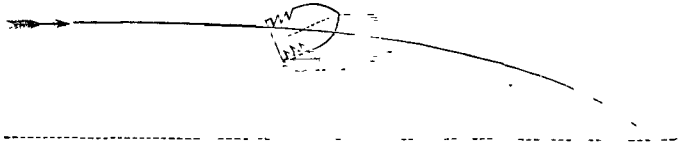


Fig. 70.—THE TAMISSIER CANNELURES OR GROOVES.

Grooves on bullets have not been used in England. Indeed their object is adequately effected by the *cavity* in the bullet, namely, to throw forward the centre of gravity so as to keep the point of the bullet in the desired trajectory. Two advantages result from dispensing with these grooves; the bullet, being no longer exposed to the considerable friction resulting from them, loses less velocity and gets a flatter trajectory; secondly, the *derivation* or tendency of the bullet to deviate towards the direction of the twist in the grooves of the rifle is diminished, because the cannelures or grooves of the bullet are one of the causes which tend most to augment that derivation. Hence bullets without grooves require less elevation, experience less *derivation*, and are consequently more accurate. Still, grooves are retained throughout the continent in spite of their inutility and impropriety in hollowed projectiles. One groove is still seen in the present perfected French regulation bullet, though very shallow, its object being only to conduce to the throwing of the centre of gravity well forward—perhaps the most important condition of the elongated projectile.

XVII. In England it may be truly averred that nothing had been effected in the matter of bullets until 1851, when, we are told, a *Minié* musket which had been found in the streets of Rome, after its last siege, loaded with the *Minié*

bullet, was sent to the Marquis of Anglesea at the Horse Guards, and, doubtless, produced as great a sensation as would a stranded ship from some civilized nation amongst the aborigines of America, whose only idea of a ship hitherto had been the hollowed trunk of a tree from their primeval forests.

Bullets made after the fashion of the *Minié* were, at least for a time, adopted in our service, but they had soon to make way for others. About that time (1851) a Small-Arms Committee was sitting, and Lord Hardinge requested the leading gunmakers to lay before it such suggestions as they might consider would effectually improve the projectile then in use. This was, perhaps, expecting too much from merely practical gunmakers, considering the amount of theoretical knowledge, in various branches of science, which was necessary to meet the requirements of a perfect projectile—a mathematical production of no mean order. However, after a series of trials with the various bullets thus brought forward, it was at length decided that a bullet furnished by Mr. Pritchett, of St. James's Street, seemed best endowed with the necessary requirements.*

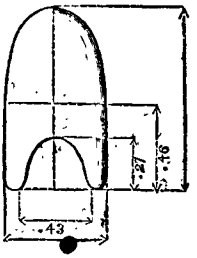
XVIII. This bullet (fig. 71) is a simple leaden cylindro-conoidal projectile, having a small cavity at the base, and possessing very good proportions. Its diameter is ·568, length 1·05 inch, and windage ·009.

The Pritchett bullet shot well from the Enfield rifle so long as its diameter was ·568, and that of the rifle ·577, but, when these conditions were not maintained, results proved that no dependence could be placed on the firing. When it is considered that three thousandths of an inch are allowed as a margin in boring the barrel, and one thousandth in manufacturing the bullet, it will be seen that it is next to

* For this Mr. Pritchett was awarded £1,000 by Government.

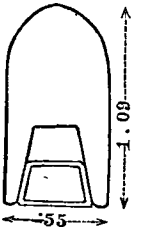
impossible to maintain the conditions precisely. With a view therefore to correct any imperfections which might exist either in the diameter of bullet or bore of rifle, the cavity in the base of the bullet was altered, and an iron cup placed there as an auxiliary to expansion, on the strong recommendation of Colonel now Major General Hay. To determine the best material and shape for the cup or plug, further experiments took place in 1855, which resulted in a new form of bullet (fig. 72), with a boxwood plug, being

Fig. 71.



Enfield Pritchett Bullet, 1852.

Fig. 72.



Improved Enfield Bullet, 1857-9.

recommended and adopted; the advantages claimed for it were:—

1st. Greater and more certain and uniform expansion, having at the same time a sufficient margin to cover any trifling inaccuracy in diameter, either of bore or bullet, caused by imperfect manufacture.

2nd. Great decrease of fouling, with corresponding facility of loading.

3rd. Increased accuracy of shooting.

Subsequently, in consequence of complaints of the difficulty of loading the Enfield rifle during the Indian mutiny, another change was made in the ammunition in

August 1857. The diameter of the bullet was reduced to ·55, and its length increased to 1·09 inches (fig. 73), and, as we stated in our last lecture, beeswax was adopted as a lubricant instead of a mixture of beeswax and tallow.

The expansion is facilitated by the length of the bullet being the double of its diameter, so that the force of the ignited powder, acting suddenly in the cavity of the base with a pressure of some 2 or 3,000 lbs. on the square inch, slightly drives in the base before the inertia of the bullet's front is overcome, or before it has had time to drive out the column of air in the tube. It thus becomes expanded throughout its cylindrical part, especially at the shoulder, the cavity at the base being designed rather to throw forward the centre of gravity by lightening the lower half of it, than to obtain expansion, although, as before occurred, it was accidentally found to subserve that most important purpose, especially when aided by the box-wood plug. This is proved by inspecting a bullet which has been fired into water or otherwise, so as to preserve its shape ; the plug, being lighter than the lead, is first moved and jammed into the lead, and it is invariably found to be driven beyond the line of the base, thus forcing out the sides (fig. 73, at *a*).

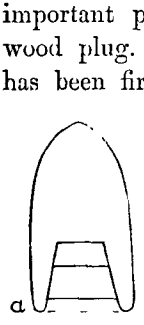


Fig. 73.

This bullet weighs 530 grains, whereas the old smooth-bore ball weighed only 480, a fact which it is proper to notice, for one of the objections to the rifle was that its bullet was "smaller" than that of Brown Bess.

XIX. By means of this expansion in the barrel, the bullet admits of considerable windage, so as to ensure easy loading. This windage, however, seems now to have reached its utmost limits ; it was formerly ·009, it is now

·027, and requires careful loading to keep the bullet "home" to the charge—an essential condition to secure the full effect of the explosion, and consequent expansion. Thus the bullet enters the barrel with a certain degree of windage, but changes its shape at the explosion of the powder, becomes thicker and shorter, and leaves the muzzle in a "forced" condition," having done away with all windage, and escaping all its consequences, so fatal to accuracy and range in the projectile of Brown Bess and her sisters. The advantages gained by the adoption of this bullet are thus summed up in our Book of Instruction:—

"Windage is completely done away with, and the whole force of the explosion acts upon the bullet in the same direction, giving it increased velocity, and obviating those irregularities which have been described as taking place during the passage of the spherical ball through the smooth-bore barrel."

Other advantages accrue from the use of the expanding bullet. Fouling is greatly diminished by the fact that the bullet, filling the bore so perfectly, sweeps out before it the deposit of fouling left by the preceding charge.

It may seem difficult to understand how this necessary "tight-fit" is effected. The difficulty vanishes, however, when we remember that property of air, as a body or "matter," to resist all attempts to dislodge it. The sudden blow of the powder-gas in the rear of the bullet drives it against the column of air in the tube; thus, between two tremendous blows, far exceeding that squeeze in a vice which would be sufficient to compress the bullet, it is easy to conceive how the lead is squeezed out and made to fill the bore completely, just as would a bullet of putty, clay or gutta-percha, with the same windage, if pressed down by the ramrod against the resisting face of the breech-pin.

Again, as before stated, the bullet has the benefit of the entire force of the powder; there is none wasted; all is inflamed in the tube; and we have been thus enabled to reduce the charge from about 5 drams to 2½ drams, thereby reducing the recoil of the rifle to a corresponding extent, and therefore admitting less weight in the weapon to resist the recoil, and lightening the load which the soldier has to carry. Moreover, the full effect of the charge thus secured greatly increases the range of the projectile.

XX. Nor are these the only advantages resulting from the adoption of the elongated projectile. The elongated bullet is also better shaped for passing through the air, from the diminished area of its anterior section.

In the important matter of "penetration and range" the elongated bullet has greatly the advantage over the spherical projectile of equal weight. The resistance which a body encounters in moving through a fluid is greater when it moves with its broad end forwards than in the opposite condition; a ship would evidently encounter a much greater resistance if it were driven sideways than when sailing in the direction of the keel; it would also meet with greater resistance if moved stern-foremost than in the usual manner. The blade of a sword would be wielded with difficulty if brandished with its flat side against the air. In the opposite condition, however, nothing is easier. The pointed or wedge-like form is, therefore, best adapted for a passage through a fluid; and nature has formed birds and fishes in this manner to facilitate their passage through the air and water.

XXI. To understand more clearly that the bullet now used is far better adapted for passing through the air than the old spherical ball, we have only to remember that the

resistance of the air is in proportion to the area of the cross sections of two similar bodies driven against it.

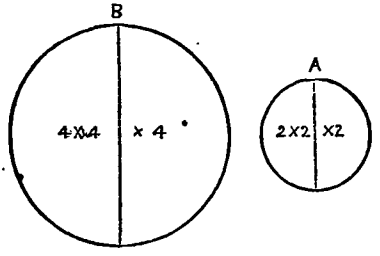


Fig. 74.

If, in fig. 74, A represent a ball 2in., and B one 4in., in diameter, the amount of resistance offered to them respectively by the air will be as 4 to 16.

But, on the other hand, the power in bodies of similar form to overcome resistance is proportionate to their *mass or cubical contents;* and the cubical contents of spheres composed of the same material is proportionate *to the cubes of their diameters.* Thus the relative power possessed in this respect by A and B would be as 8 ($2 \times 2 \times 2$) to 64 ($4 \times 4 \times 4$). Consequently, the power of overcoming resistance increases to a much greater extent relatively than the mere resistance caused by increased section.

Now, suppose a body to have the diameter of its cylindrical portion equal to that of the smaller ball A, and to be elongated (C) so that its weight is equal to that of the larger spherical ball B, in the previous figure.

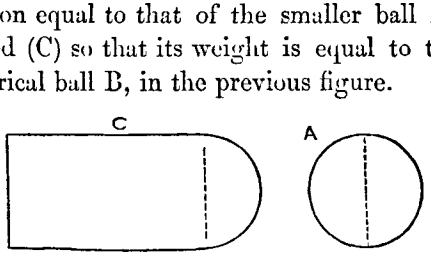


Fig. 75.

It is evident that it would meet with equal resistance from the air to that experienced by the smaller ball A, and *no more* (except a small addition from friction); whilst, at the same time, it will possess a power of *overcoming resistance* actually equivalent to that of the larger ball B, fig. 75.

XXII. Comparing, then, the relative merits of spherical and elongated projectiles, it appears that the former, though discharged with the same velocity, do not range or penetrate in proportion to their weight; because an increase of weight in their case involves a corresponding increase of section. It is otherwise with an elongated form of projectile;—its weight may be increased almost to any extent, with a proper barrel and adequate charge of powder, without materially increasing the resistance of the air to its flight; and it will, consequently, maintain a higher velocity and have greater range. Moreover, penetration depends not only on velocity, but also on the weight of the projectile. A spherical bullet cast into an elongated form, would, without additional weight, have greater penetration—simply because it would have greater velocity; but, if we retain the same diameter and give the bullet greater length, then we add more weight, and thereby give it still greater penetration. At the same time the height of the trajectory is reduced.

XXIII. On the introduction of projectiles on the expanding principle, the old musket-bore, with its diameter of seven-tenths of an inch, was retained; and a conical projectile was adapted to it. This was necessarily of great weight—696 grains, instead of 480 grains, that of the spherical bullet. So serious an addition to the weight of the ammunition carried by the soldier, soon led to a more careful investigation. After a lengthened series of inquiries and experi-

ments, a diameter of very little over half-an-inch or ·55 (originally ·568 inches), was given to the bullet, with a weight of 530 grains. Thus, in the reduced diameter and greater weight of the bullet, great advantage is obtained.

XXIV. Notwithstanding these important advantages of an elongated projectile, it does not follow that it would be the best to fire out of a *smooth-bore;* on the contrary, it would give infinitely worse results than the old spherical bullet fired out of the same piece. This results from the fact that all elongated bodies have a tendency to rotate or turn round their shorter axis (fig. 76); so that, unless something could be done

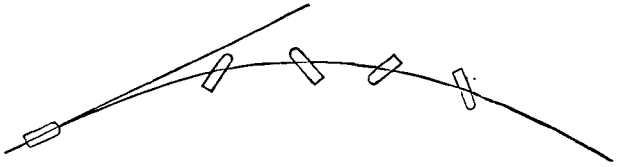


Fig. 76.

to counteract this tendency, an elongated bullet in the air would be like a ship without a rudder on the ocean.

XXV. Although the evils resulting from an excess of windage may have been entirely overcome, another cause tending to give a wrong direction to the projectile still remained to be rectified,—namely, that the form of the bullet may be distorted.

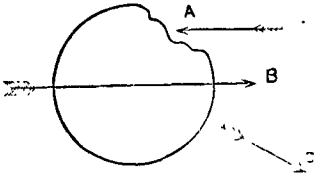


Fig. 77.

This defect in the projectile may be of two kinds—external or internal.

Fig. 77 (p. 229) represents a ball, whose external surface has received an indentation, as at A. Then, during its passage in the direction B, the air, acting on this defect, the bullet is forced out of its true course to a corresponding extent, somewhere in the direction of the arrow C; and thus the ball will be diverted from its intended path to the mark or object.

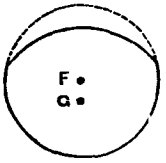


Fig. 78.

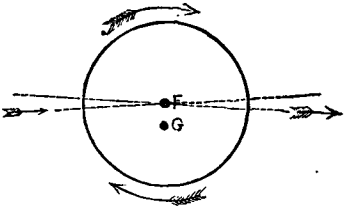


Fig. 79.

Figs. 78 and 79 represent deformities of another kind, resulting from the centres of figure and gravity not being identical. This is called *eccentricity*, G representing the centre so far as gravity or weight is concerned, and F the centre as to surface or figure. A variety of causes may produce this eccentricity in the projectile, such as holes or air-bubbles in the lead, a want of homogeneity or uniformity in the nature of the metal, or difference of density. In the case of round shot, the eccentricity is ascertained at our arsenals by floating the projectile in mercury, and marking its vertex; then a point is marked on the shot diametrically opposite to that point, thus giving the direction of the axis in which the two centres are in a line.

In fig. 80, page 231, A is the vertex as the shot floats in the mercury, B the opposite point, the centre of *figure* being C, and the centre of *gravity* D, both in the line A B.

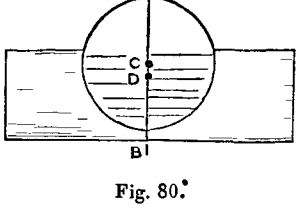


Fig. 80.

These points being ascertained, it can be placed in the gun with its centre of gravity in any desired position. When the centre of gravity is placed above the centre, the range is extended; when below, it is shortened. If the shot be "concentric," that is, should the centre of gravity and figure be identical, then any part or side of it will remain up or down, just as it is placed in the bath of mercury, in other words, the shot gravitates equally on all sides.*

It would obviously be impossible to apply such a test to the projectiles of small arms, which have to be supplied in millions, and made of lead, with which, moreover, the mercury would amalgamate, and render them unfit for service.† The new elongated bullet would be equally affected by any

* Sir H. Douglas, "Naval Gunnery."

† The floating of a body in a fluid depends upon its *specific gravity* —that is, the relative weight of equal bulks of different bodies. When we say that one substance is "heavier" than another of equal bulk, we mean that its "specific gravity" is greater. Thus water is four times "heavier" than cork, and therefore cork floats in it. Water is taken as the standard, and all other bodies are said to be more or less than water as to their specific gravity. Now, the specific gravity of iron is 7·645 that of water, it therefore sinks in it; but that of mercury is 14·019, and therefore iron floats in it; whereas the specific gravity of lead is only a little under that of mercury, namely, 11·325. Mercury amalgamates or unites with all the other metals, excepting iron and platinum; hence it is imported in iron-flasks, and can never be placed in contact with any other metals without injury.

unevenness of surface or defect of figure; such defects are, however, prevented in the first instance by the mode of manufacture, which is thus described by Dr. Wynter in his "Curiosities of Civilization:"—

The rifle itself is not a greater advance upon old Brown Bess than is the Enfield bullet upon the old one-ounce ball. The apparatus employed to produce it contrasts as forcibly with the simple bullet-mould formerly in use. Instead of heating the lead to a fluid state, it is simply warmed, in which condition it is subjected to hydraulic pressure in a large iron vessel, which has but one small aperture at the top of the size of the intended elongated bullet. (This hydraulic pressure is equal to 23,000lbs. to the square inch, and can be raised to 30,000lbs. if necessary.) Out of this hole the metal is driven in the form of a continuous rod of lead, which, as it issues forth, is rolled upon iron reels as if it were so much cotton; the reels are then attached to a machine, which draws the metal between its teeth, bites it off to the required size, moulds the cone, depresses the cup, and condenses the mass at the same moment. These wonderful bullet-makers, when in full work, turn out five hundred elongated bullets a minute, or upwards of a quarter of a million daily.

XXVI. But, assuming that owing to this system of hydraulic compression our bullets are comparatively perfect, yet they are exposed to "the chances of war": first, in the shape of hard-ramming; and secondly, in the fact that the mere thumping in a march, or in an ammunition box, in a lengthened campaign, will cause the bullets to lose their concentricity, and become distended laterally. This actually occurred in India to some bullets sent from England to the Central India field force. Owing to their ends being flattened out from the cause just mentioned, they were returned to the arsenal at Bombay as being too large for the Enfield rifle.

Now the evils resulting from defective surface and figure in the bullet, together with its tendency to topple, as it were, head over heels, are fully counteracted and neutralised

by the adoption of a rifled barrel, which will be fully discussed and explained in our following lectures. Assuming, however, in anticipation, that these difficulties connected with the use of elongated or "picket" projectiles have been overcome, and that the change from a spherical is admitted to be "for the better," there still remained a very important problem to be solved, namely, what was the most appropriate form to be adopted for this projectile.

XXVII. If we trace the successive steps of any invention, we generally find that they have been worked out in conformity with some natural contrivance suggesting the method to attain the desired success. In the present instance, the suggestion has invariably been the shape of natural objects, such as birds cleaving the air, or fishes cutting through the water. The great difficulties attending experiments in air compel us to have recourse to water as the best medium for our experiments, although far denser than that which it is intended to represent.

Now, the forms of bodies suitable for traversing resisting mediums are dependent on the velocity, volume, and surface of the penetrating body, as well as upon the nature of that which is penetrated. In general, these forms have either a *point* or an *edge*, which cleaves the body to be penetrated; a *swell*, the maximum thickness of which has a variable position as regards the whole length of the body; and an *end*, likewise terminating in a point or edge; besides curved surfaces connecting these three portions. Such are the forms of fish intended to move through the water; of birds through the air; of the submerged part of water-fowls; as well as the sections of ships and boats in the like situations. In no case is the widest part situated at the end opposite to that which forces the passage: on the contrary, it is invariably in the other part. The greater the velocity

or penetration, the more does the length of the body increase in proportion to its width; and the more, likewise, does the extreme width approach the part which penetrates. Generally speaking, fishes are from four to five times the length of their greatest depth; and are, at the same time, comparatively narrow: their maximum depth and thickness are ordinarily situated at about one-fourth or one-third of their length from the head.

Sir Isaac Newton, in his *Principia*, as early as 1687, indicated the form of body which would, in passing through a fluid, experience less resistance than a body of equal magnitude and of any other shape, and he suggested its adoption in shipbuilding. It is of a cylindro-conoidal form.

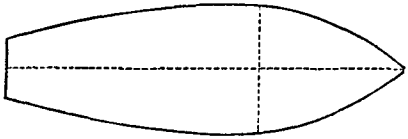


Fig. 81.

Again, in 1742, we find that our countryman Robins, to whose extraordinary genius gunnery owes so much, and to whose discoveries so little of value, comparatively, has been added, still more clearly defined what were the necessary conditions for the form of projectiles.

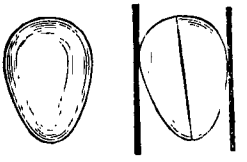
First, he clearly proved the advantages of an elongated form of projectile; and, secondly, that the centre of gravity should be near the fore part; and, with this view, he proposed the use of an *ovoidal* or egg-shaped bullet, which, having the centre of gravity in the fore part, would fly more accurately in the line of the desired trajectory; the lighter end being constantly forced by the resistance of the air into the path of its required flight.

Now, although the elucidation of these two points occu-

pies no more than ten lines of his celebrated treatise, it would not be difficult to show that all the different forms of bullets which have since been adopted, have succeeded only so far as they were in accordance with the principle embodied in those few lines which he devotes to this subject.

Robins died with his pen in his hand in 1751, but, like many others who lived before their time, he seems to have produced but little effect on the practice of his contemporaries; and nearly a century elapsed before his ideas were put to the test of practical experiment.

XXVIII. The great objection to the egg-shaped bullet was, that there was no certainty of its longer axis coinciding exactly with that of the bore when rammed home; and therefore the force of the powder had a tendency to act obliquely on the bullet, and not through the longer axis, thereby causing irregularity in the flight.



1. 2.

Fig. 82.

In No. 2 of the above figure it is evident that the axis of the projectile is not coincident with the axis of the piece, and, consequently, the primary condition to secure accuracy of flight is wanting.

On this head Owen, in his "Motions of Projectiles," has the following remarks:—"In order to secure accuracy of fire it is essential that the axis of the projectile should correspond with that of the bore of the gun; for, otherwise, the

axis of rotation will be variable, and the deflection of the projectile uncertain. Should the axis be unsteady, the projectile, on leaving the bore, will have the 'wabbling' motion so frequently observed in experimental practice. It is therefore indispensable that the 'bearings' of the projectile should extend along the cylindrical part, or should be very near the centre of the shot; for, if they be either too far forward or behind, unsteady or wabbling motion must result, from the axis of the projectile being inclined to that of the bore of the gun."

XXIX. In 1842 Delvigne, as previously stated, first endeavoured to reconcile some of the practical requirements of a projectile with the conditions indicated by Robins as essential to its successful flight; but in doing so he had to adopt a sort of compromise, by making use of a leaden cylinder scooped out internally at the base, and rounded off in front, making it a conoid or paraboloid. Thus the centre of gravity was thrown forward, whilst, owing to the surface of the greater part of the bullet being cylindrical, its axis was maintained coincident with that of the piece. This is the general form of projectile adapted to modern small arms; but, like all compromises, it is open, as we shall hereafter demonstrate, to very serious objections.

XXX. From this time forward human ingenuity seems to have exhausted itself, both in Europe and America, in giving to projectiles every form and proportion that the brain could suggest or the human eye behold; for the most part literally "without rhyme or reason" for their particular shapes and infinite variety. Invention in this matter seems merely to have said, "Try this—try that," without the slightest regard to the principles involved in the requirements of a perfect or even a serviceable projectile. There were disc-shaped, conical, conoidal, ogival,

and even "a flattened, lenticular, ellipsoidal projectile," confidently brought forward by one Count Paul de Saint-Robert, a Sardinian artillerist. Then there were compound-bullets with separate parts dove-tailing, so that they could be fired either end foremost; there were self-rotating projectiles, reminding one of the sea-serpent; bullets encased cunningly in cylinders of wood, which wooden case, on quitting the muzzle, was to vanish into "thin air," leaving the bullet to wing its flight alone, like a butterfly after shedding its larval integument! Elongated bullets have been made for smooth-bores, with their hinder parts provided with grooves, and the base split into flanges so cut as to obtain a rotation by the force of the gas from behind, and to collapse on leaving the muzzle, thus obtaining the egg-shape of Robins's projectile.

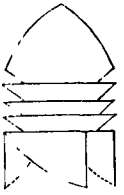


Fig. 83.

At the small Museum at Hythe the eye grows dim, utterly fatigued by the contemplation of this kaleidescopic display of man's ingenuity in fashioning his crude conceptions of "missive ruin."

Nor were these devices confined merely to the bullet itself, but even in the matter of plugs for the base a hundred materials were proposed, from iron to cork, and from horn to gutta percha;* in fine, a description of all the varieties of bullets "invented" would fill a good-sized volume, a work as useless for all practical purposes as the bullets themselves.

XXXI. For the most part these bullets were merely the result of hap-hazard ideas, or crude ill-digested notions, worked out regardless of any principle of mathematical

* The new plugs most approved at Woolwich are of baked clay.

proportion, or without any consideration even of the mechanical conditions concerned in the object. Indeed, it is only within the last two or three years that scientific men have at all directed their attention to the laws that govern the flight of all projectiles, and have studied the mechanical conditions which they require in the form of the shot, and the internal construction of the gun itself.

A projectile of the cylindro-conoidal form is resisted in its passage through the air in two ways,—first, by the pressure of the air acting against its anterior portion; and, secondly, by the friction of the air on its sides—as roughly shown in the following figure.

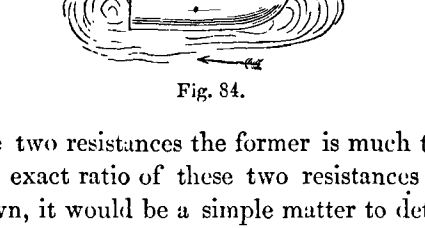


Fig. 84.

Of these two resistances the former is much the greater, and, if the exact ratio of these two resistances were accurately known, it would be a simple matter to determine the relation of length to diameter to enable the projectile to traverse the air with the least possible resistance. In the impossibility of absolute data, but from the consideration of all the requirements of a projectile, and the natural forms which it should imitate for accurate and effective flight, a definite conclusion was enunciated by the experimentalists in this important investigation; and Piobert recorded it as follows:—The form in which a body in motion will present the least resistance to the air, is that in which its length is *five-times* its greatest diameter, and its greatest diameter

should be situated at two-fifths of its length from its anterior extremity. This accords with what has been previously observed respecting the shape of fishes and of birds; and such a bullet would have the form of the following figure, being only an elongated Robins-projectile. (Fig. 85).

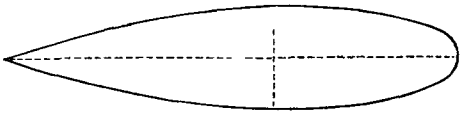


Fig. 85.

Tamissier elongated the projectile to *seven* calibres or diameters with excellent results, after complying with the necessary concomitant conditions, as will be discussed in the sequel.

General Jacob, who always combined in an eminent degree practical experiment with theoretical considerations, came to the conclusion—1, that the conoidal form was the best shape suited for the anterior part or apex of the bullet; 2, that the conical and cylindrical parts should be one diameter and a half in length each, so that the entire length of the bullet would be three diameters.

XXXII. We are not aware whether the proportions of Mr. Pritchett's bullet or the present *Enfield* were the result of theoretical investigations, or mere accidental experiment. It may be admitted, however, that the result was good; for, although little more than $1\frac{3}{4}$ diameter in length, the adjustment of the parts round the centre of gravity in the bullet is excellent; but, in common with the majority of experimentalists, in adopting so much cylindrical surface from the shoulder to the base of the bullet, in order that the axis of the shot should remain coincident with the bore, and on

quitting the muzzle possess the steadiness requisite for accurate flight, Mr. Pritchett seems to have lost sight of the fact that friction was greatly increased by having the "bearings" so extended; and, moreover, that the hind part of the bullet does not comply with the form best suited for passing through an atmospheric medium with least resistance and retardation. "The importance of establishing a proper relation as to shape and relative weight of the fore and hind part of a projectile is apparent from the fact that a projectile which is so made is found to give an increased range of 25 per cent. as compared with one with a similar shaped front and the ordinary cylindrical rear." The practical truth of these observations, made by Sir H. Douglas, is fully borne out by the fact that the projectiles that have as yet attained the greatest range and accuracy, with the flattest trajectories, are such as have conformed most closely to the principles enunciated by him.

Thus Mr. Whitworth, who has perhaps done more than any one else to determine the harmony which should subsist between the proportions of a projectile, has found that

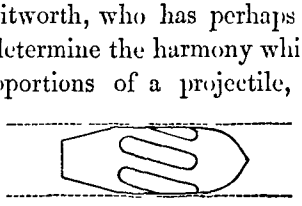


Fig. 86.

with his solid shot tapered off at the base (as shown in fig. 86), and a length of $3\frac{1}{2}$ diameters, he obtains an increased range, viz. from a $\frac{1}{4}$ to a $\frac{1}{3}$, compared with his projectiles formerly used, which had not tapering rears: he uses a flat end at the base as it gives greater steadiness to the projectile in flight. With his 1-pounder muzzle-loading gun and projectiles so formed, he has accomplished the following marvellous results:—

Calibre of Gun.	Charge of Powder.	Weight of Projectile.	Angle of Elevation.	Mean Range in Yards.
1·31 inches.	2 ounces.	16 ounces.	2°	1,050
Ditto	Ditto	Ditto	3°	1,500
Ditto	Ditto	Ditto	5°	2,240
Ditto	Ditto	Ditto	7	2,800
Ditto	Ditto	Ditto	10°	3,500*

With 3-pounders similarly constructed, the extraordinary range of 9,688 yards, more than 5½ miles, was obtained at 35° of elevation.

XXXIII. As a striking instance of the influence of the form of the projectile in modifying range, trajectory, &c., we may adduce the following facts. In 1848 the Swiss Federal Government adopted a rifle and ball proposed by Colonel Wurstemberger. The bullet was cylindro-conoidal, of about 2½ diameters, the shorter diameter being about 0·409 inch. The cylinder predominated for the greater portion of the length, and near the base were two *cannelures* or grooves to lighten the bullet posteriorly, whilst the posterior part of the bullet was a little thicker than the remainder (fig. 87). This rifle with the ball was called the "federal," and made such excellent practice that its adop-

* A few of these small 1-pounder guns would be found an invaluable addition to the armament of a regiment or any detached force. Lord Hardinge and Sir John Burgoyne were great advocates for their introduction into the service. Captain Sherard Osborne secured a number from Mr. Whitworth for the equipment of his Chinese force. The gun weighs about 70lbs, and could be easily carried on the back of a mule, or between two men. Their long range, accuracy, and penetration, could often be turned to admirable account, as for example in New Zealand at the present time.

tion was unanimously recommended by the Commission, which had been sitting with the view of selecting a fire-arm that should be superior to anything then in the service.

In 1856 an important modification was made in the shape of the Swiss projectile. The new bullet, which received the name of *jäger*, was, in the fore-part, for two-thirds of its length, something of the rolling-pin form, the bore of the gun catching only the periphery of the convexity (fig. 88), and all behind this was of less diameter than the convex portion, though it was cylindrical and had cannelures.

The two bullets were about the same length and weight, and, on the "federal" bullet being tried against the "jäger" bullet, the following differences in the angle of elevation became apparent; and it will be borne in mind, as pre-

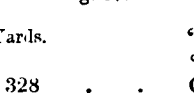


Fig. 87.

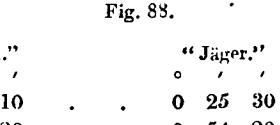


Fig. 88.

Yards.	"Federal."	"Jäger."
	° ′ ″	° ′ ″
328 . .	0 35 10	. . 0 25 30
492 . .	1 3 20	. . 0 54 20
656 . .	1 38 50	. . 1 21 40
820 . .	2 9 3	. . 1 52 40

viously mentioned, that of two guns, all other things being equal, that which fires with the lowest angle is the better.

XXXIV. The superiority of the "jäger" was attributed, 1st, to the very limited surface of the bullet exposed to friction in the barrel in comparison with that similarly exposed in the "federal" pattern; 2nd, to the shape of the projectile as affecting the amount of the resistance of the air, the charges of powder and other conditions of firing

being exactly alike ; so that, both in this instance and that of the *Whitworth* projectile referred to, the increase of range may be said to be obtained by applying to projectiles moving through the air the proper principles of construction—exactly as a ship constructed with proper lines to facilitate her passage through the water attains the greatest speed on the ocean.

XXXV. The great desideratum in a projectile is evidently to reduce its "tangential surface," and consequently its friction in the barrel ; and, at the same time, to endow it with the maximum rotation and momentum. The difficulty is to reconcile this with the necessity for keeping the axes of the shot and barrel coincident. Whitworth alone has been able to do this completely, by means of his six-sided gun barrel and projectile fitting mechanically at the shoulder; but even Whitworth has only been able to apply this principle to fire-arms of a larger description, from 1-pounders upwards. We confidently look forward, however, to the time when the apparent difficulty of its extension to small arms will be overcome.

XXXVI. So much for the form of the projectile. It would serve no practical purpose here to enter into a discussion of the best materials for bullets ; so long as the present system of expansion is retained, there appears but little doubt that lead, one of the oldest of the known metals, is best qualified for a projectile for small arms.

Lead fulfils two essential conditions in this respect in a remarkable degree: *1, it possesses great weight or mass in* a small bulk; and, *therefore, its power of penetrating the* air and attaining a great range is proportionally great; 2, its softness and ductility render it easily impressible, so that it can with facility adapt itself to the bore of a gun, whatever may be its shape at the explosion of the charge.

In selecting lead for this purpose, however, too much care cannot be taken in rejecting such as may be in any degree contaminated with foreign substances;—for the softness of lead depends, in a great measure, on its purity; and a very small admixture of other metals, such as tin or antimony, is often sufficient to harden it to such an extent as to unfit it entirely for expanding projectiles. It should also be remembered that lead becomes considerably hardened by repeated melting.

Dean states that small shot, being made of hardened lead, cannot be used in the manufacture of expanding bullets.

Theoretically, as gold contains more molecules in a given mass than lead, it is a pity that we cannot make our projectiles of that beautiful material. And sarcastic moralists might certainly say that this would be a use not at all worse than what that "root of all evil" is frequently put to; for, if the bullet be "a messenger of *death*," the "root of all evil" must be a messenger of the something *beyond it*, which must be nameless.

APPENDIX M.

The passage of a ship through the water is not a perfect representative of that of a bullet through the air;—the resistance to the former being two-fold, namely, from the air as well as the water—that from the water immensely preponderating.*

Experience has proved that this resistance depends not only on the relative position of greatest width, but, what is perhaps more

* The submerged portion of a ship is a large portion of the entire bulk; and, from its density, the resistance of water is much greater than that of air. Hence no steamer on the ocean can ever equal in speed a railway locomotive, although there is much more friction of the wheels on the rail than of a ship on the water.

important, the position of the centre of gravity of the immersed body. In a paddle-steamer, perhaps the fastest in the world, and certainly the fastest that has ever been tried in this country—we find that the position of the centre of gravity of the solid, abaft the middle of the length, is 8 feet 9 inches, the length of the ship being 330 feet. In another, of considerable celebrity, but a screw steamer,—consequently experiencing less resistance from the air, the distance of the centre of gravity abaft the middle of the length is only 3 feet 7 inches.* It is probable, however, that the speed of the latter would be increased by ballasting, so as to bring the centre of gravity more abaft the middle of the length, which is 200 feet.

It would thus appear that the position of the centre of gravity abaft the centre of the solid is made imperative by the compound resistance of air and water. This is not the case with the swiftest fishes, immersed entirely in the resistance of the water. In these the centre of gravity is invariably in the fore-part; but the fact is still more striking in microscopic animalcules, which are endowed with such lightning-like velocity in their medium. Consequently, the position of the centre of gravity in the fastest ships is no criterion for the position of the same in a projectile; but its position in the fish, or in the bird, well forward, is imperative in the bullet.

In ships the ratio of length to breadth and depth, and of breadth to depth, also differs considerably from the same ratios in fishes and birds, and especially in the latter. In the ship first alluded to the ratio of length to breadth is 9·428; in the second, 6·25; that of length to depth is 27·5 in the first, and 14·28 in the second; that of breadth to depth is, in the first, 2·93, in the second, 2·28.

All these ratios greatly exceed those of fishes, and still more of birds. It is probable that the shape of the latter is best adapted as a model for projectiles. Now *all* these affect the cylindrical in their fore-part, in which is situated the centre of gravity; and the length of the solid rarely exceeds three or four of the largest diameters —the ratio which, all other conditions being equal, will probably be that of the length to the extreme diameter in the best projectile. The ancients seem to have had a glimpse of this important requirement, for one of their sling-bullets, called *molybdides*, or *glandes*,

* I am indebted for these particulars to a member of one of the most eminent ship-building firms of the present day.

found on the plains of Marathon, and in other parts of Greece, had the following dimensions:—length, 1·18 inches; breadth, 0·71 inches; thickness, 0·62 inches; weight, 686 grains—about the weight of the Minié bullet. Such was the elongated projectile of the ancient slingers, endowed with wonderful accuracy and penetration, if we may believe historians. A projectile shaped exactly, as to proportions, like the swallow or the swift, would necessarily have its centre of gravity well-forward, and would probably give the best results from an appropriately grooved rifle.

LECTURE VIII.

[Eighth Lesson, Red Book, p. 31.]

The Rifle.

I. Considering the facts and figures adduced in the preceding Lecture, and the numerous deficiencies of "Brown Bess," it seems unaccountable that what has recently been done in the improvements of small arms should have remained so long unattempted; for, excepting the change from a flint to a percussion lock, it appears that no improvement had been effected in the small arms of the British army till within the last ten years; and that the musket with which our soldiers fought and won the battles of the Peninsula and Waterloo, under Wellington, was essentially the same which had been used, more than a century before, under Marlborough at Blenheim and Ramillies.*

II. In the preceding Lecture we confined our investigation exclusively to the *projectile*, and the important results accruing from the substitution of an *elongated* for the *spherical* bullet. But this simple change of figure would not have been attended with satisfactory results without an important alteration in the piece intended to discharge it,

* It seems, however, that not only did our soldiers fire better than the French, but that their musket, with all its defects, was better than that of their opponents; and a German artillerist, Schlimmbach, wrote a volume, to prove this fact to have been the chief cause of the inferiority of the French in their last battles with the English.—Steinmetz, "The Rifle and the Man."

namely, *rifling;* and we have now to consider this other essential link in the chain of improvements, which indeed has revolutionized the fire-arms of the present day, and made them "arms of precision" at long ranges.

It would be impossible here to enter into a detailed recapitulation of all the inventions and contrivances from time to time brought forward for the improvement of the musket; but it may be interesting to glance at some of the main steps in the improvements referred to, the stepping-stones towards our present attainment—the rifle.

III. The earliest mention of cannon in England dates from the reign of Edward III. who used four pieces against the French with astonishing effect, at the famous Battle of Cressy, on the 26th of August, 1346. As may readily be supposed, these guns were extremely clumsy and ill-contrived, wider at the muzzle than at the breech. Many of them were breech-loaders, and without any appliance wherewith to give them elevation. Indeed, at that time, such an appliance was scarcely requisite, as these guns were mostly used at very short distances, for knocking down barriers or gateways. They were called "bombards" or "crakys of

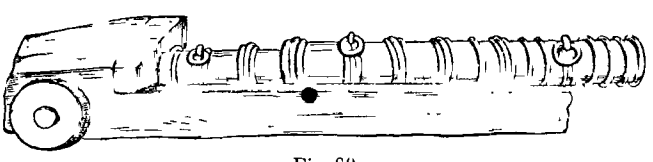


Fig. 89.

war," and were constructed by simply laying long slips of iron length-wise together, so as to form a tube. These iron bars were not welded together, but merely bound round with iron hoops, just as our modern coopers bind together the wooden staves of their barrels; hence, doubtless, the application of the term "barrel" to the tubes of guns (fig. 89).

The great "Palmerston mortar," made by Mr. Mallet, and intended for operations against Cronstadt, is constructed precisely in this manner. It throws a shell of 3 feet diameter, weighing 25 cwt.

This ancient mode of constructing cannon was abandoned and replaced by casting about the middle of the 15th century; and it is soon after this period that we first hear of small arms, or, as they were then called, "hande gunnes," of any description in England. It is, at least, certain that when Edward IV. landed at Ravenspur, in Yorkshire, in 1471, with the view of recovering the crown of which he had been deprived, he had men in his force armed somewhat after the manner represented in the following figure:

Fig. 90.

These "hande gunnes" differed in little else than size from

Fig. 91.

the smaller cannon of the time, and merely consisted of a metal tube with trunnions, fixed in a straight wooden stock, about a cubit and a half long, which passed under the arm-pit when fired.

The vent was at the top of the barrel; there was no lock nor sight of any kind; the barrels were short, and made of iron or brass. In those days the gun was, in truth, a mere tube of metal.

IV. Small arms remained in this rude and primitive form, with but little modification, till the end of the 15th century, at which epoch Gaspard Zollner, an armourer of Vienna, first suggested the cutting of grooves or channels down the interior surface of the barrel. These grooves, however, were cut perfectly straight, and were, in fact, merely introduced with the view of securing facility in loading, which was rendered very difficult after a few rounds, at the time in question, owing to the excessive fouling, from the bad quality of the powder then in use, and other causes. The idea was, that the fouling would ooze into these grooves or channels, when the bullet was rammed home; and no doubt the bore, even in this form (fig. 92), gave far better results than the smooth-bore of that period. The rifle may thus be said to be a German invention.

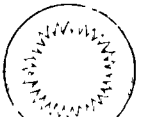


Fig. 92.

V. Although the superiority of a grooved barrel became evident, it was not to be expected that the transition from straight to spiral grooves should be made at a time when the main advantage to be derived from grooves was not understood; and it is somewhat remarkable, that more than a score of years elapsed before Koster, a gun-maker of Nuremberg, introduced the innovation, giving to the grooves a spiral turn; and thus transforming the barrel into what is

termed "a female screw," that is, a surface ground to receive a screw. It was mere accident, not theoretical design, that led to this important alteration in the internal arrangement of the barrel. Experience, however, immediately proved that accuracy of shooting was very much increased by the change.

VI. In spite of this fact, the rifle failed to become an arm of war, excepting on a few occasions; and it remained only the favourite weapon of the deer-stalker and the chamois-hunter for a term of more than 200 years. Moreover, if we except the invention of hair-triggers and more carefully contrived sights, there was, during the whole of that time, no improvement in the rifle. We are naturally led to inquire into the cause of this stagnation, and we find that it proceeded mainly, if not entirely, from the fact, that the form of the projectile used was *spherical*, to which it was impossible to give self-expansion; for, although they had recourse to a number of devices, such as have been detailed in the previous lecture, in order to give the ball the rotating benefit of the grooving, these contrivances, with the exception of the breech-loading principle, were all on what is termed the "forcing system;" getting expansion by mere mechanical violence and force. This system greatly increased the accuracy of shooting up to a certain point; but it was at the sacrifice of those great requisites in military fire-arms, facility and rapidity of loading. As long, therefore, as the rifle continued to be used in conjunction with the spherical projectile, and retained this difficulty of loading, it was utterly unsuited for the general use of an army, especially in the 18th century, when, it is notorious, all battles were decided by the rapid firing of deployed lines. Whilst such tactics prevailed, the old smooth-bore, with all its glaring imperfections, was still the preferable weapon.

This preference continued during the last great war, and Napoleon himself, no mean judge in such matters, used to say that rifles were "phlegmatic arms," more congenial to the stolid temperament of the Teuton or Anglo-Briton than the hot blood and impatience of the mercurial Gaul; and on one occasion, whilst inspecting a battalion of German rifles, who loaded as before-described, he was heard to exclaim, "Surely this is the most unfortunate weapon ever placed in the hands of a soldier." Still more recently, when there was less ground for this objection, our Iron Duke was heard to say, in a far more intolerant spirit respecting rifles, that "*he could not bear them!*"

VII. The fact was, that at the time in question—the end of last century and the beginning of the present—there was merely a choice of two evils in the matter of firing: on one hand the smooth-bore system, that is, celerity without certainty; or the rifle-system of the day, securing a degree of certainty without celerity. Hence, it became a problem to devise a system which should combine the accuracy of the rifle with the rapidity and ease of loading hitherto exclusively confined to the smooth-bore musket.

What rendered the solution of this problem more imperative, was the gradual change brought about in the tactics of the battle-field incidental to the American War of Independence and the French Revolution. Extended order was introduced. The combination of skirmishers with lines or columns became essential characteristics of modern fighting. During the greater part of the day, the masses were kept back—held in reserve—or employed in manœuvring, so as to concentrate on the weak point of the enemy, to be hurled upon it at the decisive moment. In the meantime, the skirmishers and their immediate supports were constantly engaged.

The mass of the ammunition is spent by the skirmishers; and the objects they fire at are seldom larger than the front of a company. In most cases they have to fire at single men, partially hidden; and yet the effect of their fire is most important; for every attack is both prepared, and in the first instance met, by the skirmishers. Moreover, they are expected to weaken the resistance of detachments, as well as to take the edge off the attack of a charging line.

Now, with the old "Brown Bess," none of these things could be done effectually. Any one who had been once under the fire of skirmishers armed with smooth-bore muskets could not fail to take home an utter contempt for its effect, at any ordinary distance; whilst the rifle, up to the time in question, was fatally inefficient, owing to its slowness of loading. Thus, with the introduction of skirmishing into modern tactics, arose the demand for an improved weapon of war.

VIII. As might have been expected from the warlike disposition of the people, and their wonderful military organization, this demand was first met in France; and the immediate circumstances that led to this result may be traced to the flying war which was kept up by Abd-El-Kader, the Arab chief, against the French, on their first occupation of Algeria. It was found that their men were picked off at distances at which the French musket was, apparently, powerless. The Arabs had no rifles, it is true, but merely smooth-bores, like the French; but their matchlocks were much longer than the French muskets; and, moreover, the Arabs were, for the most part, trained marksmen. Accordingly, the French found themselves positively at a disadvantage in their conflict with these rude Orientals. If only, therefore, to counteract the supposed superiority, and put themselves on terms of equality with

the enemy, it became necessary for the French to adopt a better arm.

IX. With this view the School of Musketry at Vincennes was instituted, and a series of elaborate experiments ensued, the results of some of which, with reference to the first attempt to get expansion in the ball by mechanical force, have been described in the preceding lecture. We may sum up the general result by stating that in 1828, Delvigne, the French officer before named, was the originator of the system by which the rifle has been made a weapon fit for general infantry use; and this he accomplished by establishing the two great principles on which all succeeding inventors have been obliged more or less to rely:—

First, that, in muzzle-loading rifles, the projectile must go down with a certain amount of windage, so as to admit of easy loading; and must change its shape, so as to enter the grooves only *after* it has been rammed home:—secondly, that elongated projectiles are the only ones adapted for modern rifles.

Delvigne thus at once put the question on its proper footing, and fully deserves the name of the father of the modern rifle; for to Captain Minié, who has somehow obtained so much of the honour that rightly belonged to his predecessor, is merely due the credit of perfecting details in the Delvigne rifle and system. This system, in various forms and with many improvements, is rapidly superseding the old armament which flourished for three centuries in civilized Europe.

X. Thus, at length, a rifle and bullet were constructed upon principles which rendered it possible to give this arm to every foot-soldier.

This country is naturally so conservative—so averse to the introduction of novelties—so attached to ancient law and

landmarks—that the introduction of these improvements into our service was attended with much difficulty and opposition, although "the inexorable logic of facts" had incontestably demonstrated the in feriority of thesmooth-bore musket then in our service. It was actually maintained both in and out of Parliament that the British musket was the best ever put into the hands of a soldier; and for a long period no change was made—not even after the experience of the Caffre war; although at the Cape, it is not too much to say, that, man for man, the naked savage, with his rude weapons, proved more than a match for the best-drilled soldier of the most skilful nation in the world in the art of production. In vain we tried platoon and file-firing against a few men skulking behind rocks or hidden by bushes; they could shoot us, but we could not hit them; and thus those inglorious wars went on to a disagreeable length, simply because we could derive no benefit from the lesson thus taught us, nor interpret its obvious suggestions, like the French with *their* "Caffres" in the North of the same continent. Not until the feelings of the country were fairly roused on learning what other countries were doing in this matter, and how inferior our armaments were to those of other troops, were steps taken in this most important matter.

It was not that there were no rifles in the British army. As far back as 1800 a seven-grooved rifle had been introduced; and subsequently a two-grooved rifle, known as the "Brunswick-rifle," was given to some companies of our regiments; but both of these were constructed on a bad principle. It was not until 1851 that rifles on the new Delvigne-Minié principle were introduced by the Marquis of Anglesea into our service.

XI. The rifle thus introduced had four spiral grooves, with one turn in 6 feet 6 inches; the diameter of the bore

was ·702 inch, and that of the bullet ·690 inch; the weight of the bullet was 680 grains, and its form and construction were as already fully described.

The results with this rifle were very unsatisfactory, chiefly in consequence of the shape of the bullet, and although used by our troops during the Caffre war in 1851, and in the Crimea at the battles of the Alma and Inkerman, it was never generally issued.

At length, however, in 1852, Lord Hardinge took a step in the right direction, by inviting the leading gunmakers throughout the country to enter into competition in order to furnish the best possible military weapon. In this country, and in this century, when a thing is "wanted," it need only be thrown open for competition to ensure a supply to the demand; and, accordingly, this call was promptly responded to by the following well-known gunmakers—Purdy, Lancaster, Greener, Wilkinson, and Westley Richards. At the same time a Small Arms Committee was appointed to sit at Enfield, to adjudicate on the rifles brought forward. With these rifles and the bullets provided for them, many experiments were tried during the summer of 1852; and, although some gave most excellent results, yet all of them were found deficient in one or more essential particulars. One element alone they all had in common—a reduced bore. Hence the Committee, very wisely it would appear, instead of selecting any rifle in particular, combined or embodied the good points of the whole in one, which is the Enfield rifle of our day—a rifle not the invention of one man, but of the collective wisdom of many.

XII. The Enfield rifle is but one of the modifications of the Minié. It is entirely manufactured by machinery at the Government factory at Enfield, whence it takes its name.

By means of a beautiful system of machinery, a thousand complete rifles are turned out in a week, with a degree of accuracy and finish such as the hand of the most skilful mechanic could never impart. All the various parts of the lock, stock, and barrel are made with such a nice degree of accuracy, with reference to each other and the standard pattern employed, that a rifle with bayonet, and every other part complete, may be put together in five minutes from any set of parts selected at random from a heap of the same kind!

This principle of manufacture has received the name of "interchange;" and it has been effected by the introduction of what are termed "copying machines," originally designed for copying the fine lines of statuary, so as to transfer them to ivory and other materials. The Americans were the first to apply this most ingenious machine to making rifles, and recently to boat-building.

XIII. The dimensions of the Enfield rifle are as follows: total length with bayonet, 6 ft.; length of barrel, 3 ft. 3 in.; total weight with bayonet, 9 lbs. $3\frac{1}{4}$ oz.; weight of the barrel, 4 lbs. 4 oz.; diameter of the bore, ·577 in. There are three spiral grooves ·262 in. in width, equidistant, having one turn in 78 in., a depth of ·015 in. at the breech, and ·005 in. at the muzzle. It is thus made "progressive," that is to say, it is deeper at the breech than at the muzzle, so that the bullet gets a last nip or pinch just before quitting the muzzle—the advantage of which is not very evident; indeed, obviously, it must diminish the initial velocity.

These grooves have a turn or twist equivalent to one turn in 6 feet 6 inches, or half a turn in the length of the barrel; and they lie at an inclination of 1° 19′ 11″.

The correct estimate of the comparative inclination of the grooves in two rifles of different calibres, is the angle of

inclination of the line showing the groove on the developed surface of the bore of the piece. Knowing the calibres, all we have to do is to lay off on a line the length in which one turn or twist is completed, and then lay off at right angles to this the circumference of the bore. By completing the rectangle we get the developed surface, whose diagonal is the groove, and the angle it makes with the side of the rectangle is the angle of inclination. Thus, take

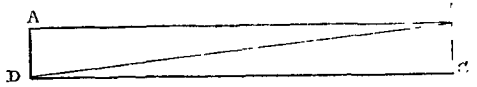


Fig. 93.

two lines, AB, BC, equal or having the same ratio to the distance on which one whole turn is completed and to the external circumference of the bore respectively, and describe a rectangle ABCD (*fig.* 93). Draw the diagonal BD. Then BDC, the constant angle at which the direction of the grooves is inclined to the axis of the bore, is the true and proper measure of the twist.

The nature of this turn or twist in the rifle may be readily illustrated as follows (fig. 94). Take a right

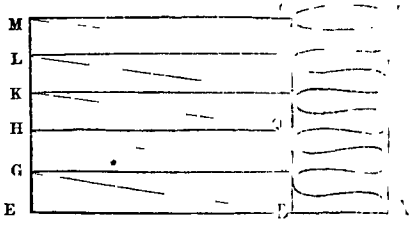


Fig. 94.

cylinder, ABCD, and develop or roll out its surface on the rectangle BEMC. Then divide the lines BC and EM, the

height of the cylinder, into equal parts, and draw the diagonals BG, RH, QK, PL, OM.

Now roll or wrap the *rectangle* round the *cylinder*. Then these diagonals will describe a continuous *curve* called a *helix*. Each forms a *spiral*, from B to R, from R to Q, and so on. The parts of any given element of the cylinder, as BR, &c., between two consecutive spirals are equal; and this constant interval is called the turn or twist of the helix or groove.*

XIV. The *Enfield* is superior to almost all the rifles served out to continental troops. It is about the same weight as the French rifle, but of much smaller calibre—the latter retaining the same calibre as that of the old smooth-bores; indeed, the great majority of the French army-rifles are merely smooth-bores "transformed" into rifles.

Although the Enfield may not be the best weapon invented, it is incomparably the best that any troops have as yet been generally armed with; and certainly it is the best that the British soldier ever had placed in his hands. It is simple in its construction, and, whilst combining all the advantages of a rifled fire-arm, it is loaded with even greater facility than the old smooth-bore.

Of course further improvement will be made in it. In course of time perhaps the bore will be still further reduced, should there be no valid objection to the reduction in a military weapon, whose cartridges should not be much longer than at present. The present system of muzzle-loading may eventually be superseded by that of breech-loading. Admitting all these possibilities and probabilities, still we are justified in regarding the Enfield rifle as the climax of those experiments which the scientific men of

* Wilcox.

England and France have carried on for the last thirty years, and it is a weapon of which any nation may well be proud.

XV. Having thus briefly traced the rifle through its various phases before it assumed its present state of "advanced development," I shall now proceed to explain why it is that the rifle, in conjunction with an elongated projectile, produces such a wonderful improvement in practice.

Whilst the expanding bullet did away with the evils of excessive windage, its elongated form rendered it useless in the smooth-bore or old musket, for the reasons previously given. Owing to the pressure of the air acting unequally upon it after leaving the bore, it soon complied with the tendency, inherent in all elongated bodies projected through the air, to turn over on their shorter axis, or, in musketry phraseology, "upsetting," so that it is obvious, that, unless an elongated bullet could be enabled to maintain its longer axis coincident with its proper trajectory after quitting the muzzle, it was utterly useless as far as accuracy and range were concerned.

Moreover, although the system of hydraulic pressure has had the effect of giving bullets the requisite homogeneity, still external flaws or asperities of the surface would sometimes occur, and would exert a most injurious effect on the bullets in their passage through the air, in addition to their natural tendency to upset. And, independently of any defects in its surface, the bullet when discharged from a smooth-bore gun, and having a motion of rotation upon some accidental axis given to it by its last collision with the side of the barrel, will, in consequence of that rotation, be unequally affected by the resistance of the air and deflected from its course in the direction in which it happens to rotate.

XVI. These evils in the use of elongated bullets are entirely neutralised by rifling the barrel, or converting the bore into what is called a "female screw;" for, on the explosion of the gunpowder, not only is the bullet made to fit the barrel tightly, but, the softness of the lead yielding to the violence of the force, the cylindrical surface becomes moulded to the shape of the rifling, so that it becomes as it were a screw exactly corresponding with the grooves and *lands* of the bore. Thus, the bullet is forced to follow the sweep or turn of the grooves, and, besides its simple motion of translation or progress, it becomes impressed with a constant rotation or spin round its longer axis.

The effect of this rotation is to maintain the longer axis of the bullet, at least during the first portion of its progress, coincident with, or in the same direction as, its proper flight, in scientific terms, "tangential to the trajectory;" and moreover, by means of this rotation, any imperfections on its surface are brought rapidly round from one side to the other of the axis, the air's resistance being thus equally distributed around the front section of the bullet. Thus, any deflection which might have arisen from these inequalities of pressure is corrected at each half rotation of the projectile, and this all-important effect constitutes the superiority of the rifle over the smooth-bore.

XVII. Rotation keeps the axis of the projectile in the same direction, and imparts *stability*, by which is meant, that, instead of turning over and over or round and round like a walking-stick thrown in the air, the projected bullet, or at least its longer axis, constantly retains the same relative position as regards north and south, east and west, and up and down—in scientific terms, it remains parallel to itself throughout its flight. A bullet projected point foremost, and retaining this position throughout its flight, the point

neither drooping nor becoming more elevated, has the term "stability" applied to its motion.

Scoffern, in his work on projectile weapons of war describes this somewhat differently, by remarking that "when a quality is two-sided or two-ended, so that one side or one end is the exact reverse of the other, philosophers call such two-sidedness or two-endedness 'polarity'; thus, magnetism is said to be dual, or a twin-joining of polar forces. There is a north-pointing extremity of the suspended magnetic needle; there is also a south-pointing extremity,—hence the origin of the designation 'polar.' With equal propriety may the designation be applied to missive weapons." Those which pursue their flight through the air, always keeping one end or aspect foremost, may be said to possess polarity, and the term in this sense is identical with that of "stability."

The greater the rapidity of the rotation imparted to a projectile, the more stable will be its axis during its flight, and the greater will be its accuracy in consequence of that stability.

There are, however, limits to this velocity of rotation. To increase the velocity of rotation a sharper twist is required in the grooves, causing greater friction, and therefore requiring a greater charge of powder, with, consequently, a greater strain on the metal.

The longer the projectile, the more rapid should be its rotatory motion to secure stability. Of two projectiles of equal weight, the longer will require greater rotation, and therefore a sharper twist in the grooves of the rifle.

The *rate* of rotation in the bullet is found by dividing the initial *velocity* per second by the length comprising the turn or twist of the rifle. Thus, if the initial velocity of the *Enfield* be 1,248 feet, and the twist 1 in 6 feet 6 inches, then the rate of rotation of the bullet will be the quotient

of 1,248 divided by 6 feet 6 inches, namely, 190·5 turns per second (1,248 ÷ 6·5 = 190·5).*

XVIII. If it should now be asked *how* the rotation of an elongated projectile imparts to it this stability, the answer is simply, that, being impressed with a motion of rotation upon one axis, it resists any impulse tending to impart to it a rotation at the same time upon another axis, so as to destroy its stability. All this and much more can be beautifully elucidated, and the effects practically demonstrated, by means of an instrument called the gyroscope,† invented by a M. Fessel, at Cologne, in 1853. Messrs. Elliott, scientific instrument makers of Charing Cross, have brought out an improved modification of this instrument, furnished with a small elongated shot (*a*, fig. 95), instead of the disc used for ordinary experiments. The rings are so arranged that one can turn round a vertical axis, and the other round a horizontal axis—the projectile being, therefore, free to turn in any direction.

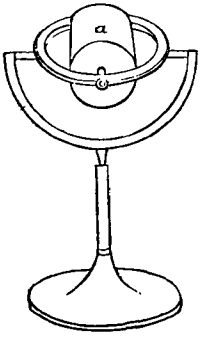


Fig. 95.

A cylindrical portion of metal extends beyond the base of the shot, in prolongation of its longer axis, round which the string is wound, to give the required rotary motion to the projectile.

* This is the initial velocity imparted by the *Enfield* in its clean condition; after firing 1,020 rounds it is 1,157 feet. From the results of recent experiments of the Ordnance Committee it would appear fallacious to suppose that a smooth-bore gun must have greater velocity than a rifled gun. They state emphatically "that was an error."—*Report of Ordnance Select Committee*, March, 1863.

† In the absence of a gyroscope, the patent gyroscopic top, everywhere procurable, will serve as a cheap and useful substitute to illustrate the subject.

As the shot in the gyroscope has no motion of translation, a strong current of air must be directed upon it, so as to represent the resistance of the air to a projectile moving with a high velocity. When this is done the following facts are established:—

That the tendency is for the axis of rotation always to remain parallel to its original direction; so that when elongated projectiles are fired at a certain angle of elevation—slanting upwards into the air—they gradually make a larger and larger angle with the tangent of their course or trajectory, as shown in fig. 96.

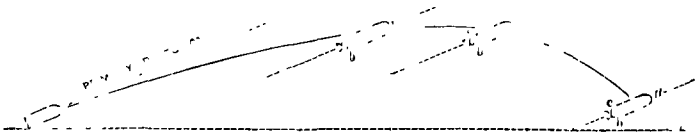


Fig. 96.

Here, then, it appears that, instead of merely having the front or fore-part of the bullet at *a* penetrating the air and meeting its condensed particles, we have the entire lateral surface, from *a* to *b*, pushed obliquely against the atmospheric molecules.

It may now be asked where are all the advantages claimed for an elongated projectile, if it no longer presents a small frontage to the resistance of the air? Still it is really owing to this supposed defect that the range of projectiles has so often and so unaccountably exceeded that allotted to it by the most careful calculations; and a moment's reflection will explain the seeming mystery.

As a bird, with out-spread wings listlessly poises itself on high, by simply opposing its breast to the air or passing wind, and as the paper kite is in like manner supported, so

is the elongated projectile; for, having attained the highest point of its trajectory, instead of rushing point downwards towards the earth, it is buoyed up and sustained by opposing its under-surface, as it were its breast, to the air. It is true that the specific gravity of the bullet is incomparably greater than that of either bird or kite; but are not these also incomparably heavier, specifically, than the air in which they float? Thus, the same cause which suspends them indefinitely in mid-air retards the fall of the projectile, and permits it to increase its range. Therefore, although it is true that air *impedes*, yet, on the other hand, it is equally true that it *supports*, the projectile, counteracting and preventing gravity from exerting all its downward influence to bring it to the ground.

XIX. Hence it actually appears that at certain elevations the range of the elongated projectile is positively greater in the atmosphere than it would be *in vacuo!* As this is a point of great practical importance, we shall quote Sir W. Armstrong's explanation of the subject:

In a vacuum the trajectory would be the same whether the projectile were elongated or spherical—so long as the angle of elevation and initial velocity were constant; but the presence of a resisting atmosphere makes the remarkable difference, that while it greatly shortens the range of the round shot it actually prolongs that of the elongated projectile. This appears at first very paradoxical, but it may easily be explained. The elongated shot, if it be properly formed and have sufficient rotation, retains the same inclination to the horizontal plane throughout its flight; and, consequently, acquires a continually increasing obliquity to the curve of its flight. Now, the effect of this obliquity is that the projectile is, in a measure, sustained upon the air, which meets the inclined surface, and the result is that the descent is retarded, so that it has time to reach to a greater distance.

Thus the range of an *Armstrong* 12-pounder, at an angle of 2° elevation, is 980 yards; whereas *in vacuo* it would

be only 838 yards. Therefore, the range of the projectile in air exceeds that *in vacuo* by about 140 yards.

In accordance with this fact we may quote the following astonishing ranges of projectiles from rifled ordnance, in which, of course, the principle in question exerts its greatest influence.

A 32lb. shot, fired from an *Armstrong* gun of 26 cwt with a charge of 6lbs. and an elevation of 33°, ranged 9153 yards.

A 3lb. shot, fired from a *Whitworth* gun, with an elevation of 35°, ranged 9688 yards.

A shot weighing 175lbs. fired from a gun made by Mr. L. Thomas, weighing 6 tons, with an elevation of 37½°, attained a range of 10,075 yards, or nearly *five miles and three quarters!*

XX. Thus it would seem as though Tartaglia and the old-world theorists were right after all in their opinion that the air aids rather than retards the progress of a projectile, which, in the sense we have explained, it possibly does to all intents and purposes. So true it is that the spirit of progress in this nineteenth century frequently ends in a recurrence to ancient ideas. When we laughed at our "rude forefathers" for believing that the air had no effect in diminishing the range of their arrows, it seems they were right after all, for owing to the support of the air *their* elongated projectiles or arrows—like our rifle-bolts—ranged further than they would have done even *in vacuo*, and so, to use the words of Galileo, "when we have the decrees of Nature, authority goes for nothing."

It is but right, however, to add here, that this doctrine has been strongly assailed by other able men, and as it has been at least disputed, though not confuted, we must accept it for the present "with a grain of salt."

XXI. This theory, however, with respect to *small-arms* must undergo a considerable modification in practice, on account of the drooping of the point of the projectile; so that, after all, the longer axis of the bullet may, throughout a considerable portion of its flight, approximate to a tangent to the trajectory, as in the figure below; which

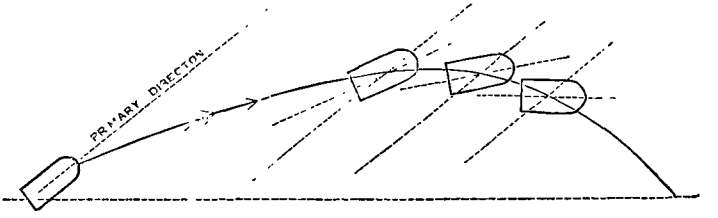


Fig. 97.

will fully explain the fact, that, in spite of the undoubted tendency to continued parallelism in elongated projectiles, yet at distances of 700, 800, 900, and 1,000 yards, bullets invariably impinge on the target as though they struck point-foremost, as at the shorter distance.

XXII. In the next place, the gyroscope, combined with the results of direct experiment, shows that the very causes which make the fire of a rifle accurate tend also to make it inaccurate—paradoxical though it may seem. This may be shown as follows. The axis of rotation having, as we have seen, a tendency to remain parallel to its original direction, it is evident from the figure 96 that, if the direction of the axis of rotation $a\,x$ remains, as there shown, parallel to the original direction or elevation of the piece, the bullet will not always remain with its point only in the direction in which it is moving, but one side of the bullet will be partially opposed to the action of the air. And, as the bullet is rotating on its axis $a\,x$, the friction arising from its pressure on the condensed air in front at $a\,b$

will produce an effect similar to that of the paddles of a steamboat, and turn the bullet sideways from its proper line of flight. The result of this force is to deflect the bullet by constantly changing its general direction towards the side to which the rifling or twist of the grooves is turned. This deviation is what the French term "derivation," and is best known in England as "drift."

XXIII. The manner in which the air presses against a projectile to make it drift may be compared to the action of the wind and sea against a ship. If the wind happens to be a good many points afore the beam, the ship is said to be "close hauled *on* the wind," and she will move forward slowly, at the same time making what is called lee-way"—otherwise "drifting" alee, at an angle proportionate to that of the course which she can make good on the wind in question;—the closer she is "hauled on the wind," the greater the drift or lee-way.

In the experiments which were carried on lately by the Select Committee on Small Arms, &c., on a nearly calm day, the mean deflection from the point aimed at, in twenty rounds from each of the small-bore rifles at 500 yards, was as follows:—

Whitworth	0·81 of a foot.
Enfield small-bore . . .	0·30 ,,
Westley Richards . .	0·45 ,,

Again, when firing at the very long range of 9,000 yards with the *Whitworth* gun, the 3-pounder threw constantly to the right—the direction of the twist of the grooves—from 32 to 89 yards.*

* Besides this deviation, or, as it is called, "derivation," there is another, still more inconsiderable, but nevertheless not without its influence in very long ranges, namely, the deviation caused by the

It must be remembered, however, that this inaccuracy, being to a certain extent regular and known before-hand, is not of so much consequence, as it can be allowed for by the arrangement of the sights, and this is actually now done, both in ordnance and small arms. And where the rifling is from right to left, as is generally the case, most gun-makers now place the zero, or centre of the line of the wind-gauge sight—and in ordinary rifles the fore-sight—not in the middle, but considerably to the right of the axis of the piece, as much in fact as will make allowance for the drift at 500 yards.

XXIV. Lastly, the gyroscope shows that the position of the centre of gravity in an elongated shot is all-important, and that, as a general rule, it should be about two-thirds forward.

XXV. Having shown how a rotary motion imparted to the bullet prevents its upsetting in its flight, we shall now

rotation of the earth. This curious subject has occupied the minds of several mathematicians, amongst the rest Poinsot, Lionville, and lastly Paul de Saint-Robert, who has completely demonstrated the theorem. It appears that, by virtue of the earth's rotation, projectiles fired towards any point of the horizon suffer, in our latitudes, a deviation which constantly takes place towards the right of the observer placed at the point of departure, and turned towards the trajectory. This deviation does not vary much when the fire takes place in different vertical planes; it attains its *maximum* in a direction of fire comprised between the south and the east; and a *minimum* in the opposite direction. The deviation will be towards the left in the southern hemisphere. Although this terrestrial deviation is very small when compared to the deviations resulting from the accidental causes which render practice irregular, still it cannot be entirely neglected in the long range of an *Armstrong* or a *Whitworth* cannon. It has amounted in certain cases to 2·46 metres, more than 6 feet 6 inches, in others nearly three yards, at 5,000 metres.

explain how the evils arising from defective surface or figure are remedied by this rotation.

The roughness and inequalities upon the surface of a bullet may be likened to the barnacles on the bottoms of ships, which both retard their motion and affect the steerage. A striking instance of the latter was afforded recently in the case of an iron vessel of war which, with the view of testing the comparative merits of two different compositions for preventing the fouling of the iron, had been coated on one side with one composition and with another on the other side. The result was that one side of the vessel's bottom became much more foul than the other, and steering in consequence was found to be next to impossible. The result of inequalities of surface in the bullet would be similar, if its motion, like that of the ship, were without rotation. The manner in which this is counteracted by the rotation is as follows:—

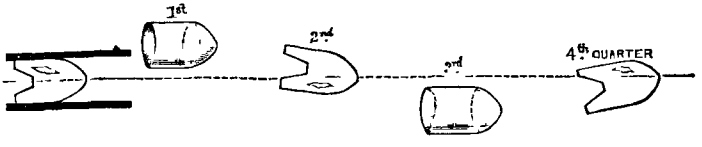


Fig. 98.

It will be observed in the above figure, that the position of the supposed flaw in the bullet which has not yet left the muzzle of the piece is above, and therefore the centre of gravity in the bullet may be assumed to be below, its axis—there being, by the fact, less metal above than below it. Directly, therefore, the bullet quits the muzzle of the piece, the air would give it, with respect to the line of fire, the position which it may be seen to occupy in the figure at the fourth quarter, that is, the position to which it returns after

completing an entire rotation; and this is the position which it might occupy throughout its whole flight, did not the rotation of the bullet on its axis effect the changes delineated in the figure; for, supposing the projectile to have received a right-handed rotation, that is, from left to right, as in the *Enfield*—then, by reason of this flaw and the consequent position which the bullet tends to take, as at the fourth quarter, the condensed air in front would have a tendency to drive the bullet upwards from the line of fire; but, as the bullet turns on its axis, this tendency will ever be changing,—so that, at the end of a quarter-rotation, the bullet would be as represented in the diagram as the *first quarter*.

Another quarter-rotation will give the bullet the position marked *second quarter*. Here observe the change in the position of the flaw. The *third quarter* and *fourth quarter* rotations will bring the bullet back as great a distance to the left as the *first* and *second* influenced it to diverge to the right, and so on throughout its flight.

Such is, as near as possible, the mode of rotation in the case in question in connection with the effect of spiral motion on a projectile, which is described as follows in our Book of Instruction:

The best way of describing the motions of a rifle projectile in its passage through the air is by means of a bent arrow, fig. 99. Suppose the arrow was shot from the point A, with a view to hit the mark C, and no spinning motion was given to it; if the bent point of the arrow were placed upwards, the greater pressure of the air being on its convex side would tend to carry it in the direction D; but, if it had previously received a spinning motion, then, by the time it reached E, the point would have turned in an opposite direction and have proceeded downwards, descending as far beneath the true "trajectory," in so doing, as it had at first risen above it; thus the arrow would continue throughout its course to move in a spiral direction round the true "trajectory," constantly correcting the error due to

its imperfect figure, and ultimately it would strike much nearer the mark than if it had received no spinning motion.

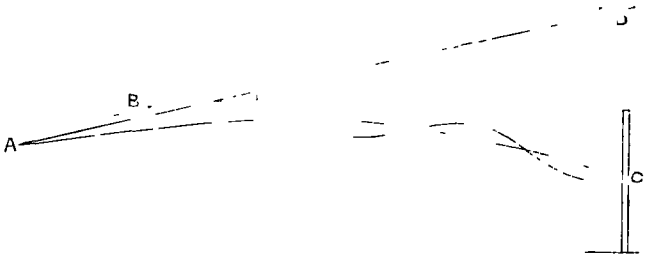


Fig. 99.

Thus, the evils resulting from any defect in the figure of the bullet are, to a great extent, rectified, but the soldier must not on that account imagine that he may neglect the caution given in the fourth motion of the rod, that "all strokes that may indent the surface of the bullet are to be avoided." An indented bullet will never go so well as one in every way perfectly symmetrical. The golden hint as to "two steady" pressures must always be applied.

> Aye, let your "home" be "sweet" indeed, my friend—
> Badges, pence, twopences on it depend.

Hard ramming, moreover, makes the powder "meal," or at least compresses the grains so much that the interstices between them—so essential for the rapid transmission of the flame of ignition—close up, and the action of the powder is impaired, so that the bullet falls short of the mark.

XXVI. In conclusion, having fully explained the nature of the rifle and the effect of rifling, it only remains for me to sum up with the statement, that all the increased accuracy in shooting with the present service arm is due to the spinning motion imparted to the bullet by means of the spiral grooves in the barrel. Rotation is the bullet's life and soul, it acts

as the rudder to a ship, keeping it true to its course, and ultimately causing it to reach its destination.

Hence, whatsoever tends in the least degree to clog or impair the action of the grooves will impair the efficiency of our shooting in all its requirements—as to direction, force, speed, and penetration.

The depth of the grooves at the muzzle being merely the *two-hundredth* of an inch, the thickness in fact of the thinnest tissue paper, the slightest particle of rust or dirt will impair their action; for it is obviously impossible that the lead of the bullet can enter into this delicate grooving if it is already occupied by another substance. Hence the paramount necessity of keeping the inside of the barrel scrupulously clean. If there be a weak point in the Enfield system it is its susceptibility to every thing in the shape of dirt.

Those who have visited Dover Castle will recollect a very handsome Dutch field-piece, popularly known as "Queen Elizabeth's Pocket Pistol." The following couplet is engraved on its surface:

> Sponge me well and keep me clean,
> And I'll throw a ball to Calais Green.

In other words, it means to imply that, provided it be kept perfectly clean, it would project a ball across the Channel. No doubt the gun brags, but it appears to me that this same couplet, after the lapse of some three centuries, may, with but slight alteration, be applied to the Enfield rifle of our day; with more regard to truth, there might be engraved on each Enfield barrel—

> Sponge me well and keep me clean,
> And I'll *carry as far as can be seen.*

APPENDIX N.

Derivation or Drift.

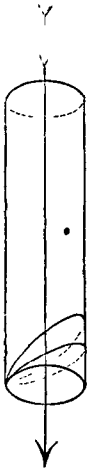


Fig. 100.

In the case of the bullet the molecules of air react parallel to the direction of the motion of translation or forward motion, and in the inverse direction of the latter, so that, if the fore-part of the projectile is plane and perpendicular to that direction, the resistance of the air acts perpendicular to it, whilst, if this surface be not perpendicular to the direction of the motion, the resistance acts obliquely. The molecules touched can glide easily beside it, the inertia they oppose is considerably diminished, and the total resistance becomes much less. As this effect is produced to a greater extent just in proportion as the fore-part is more inclined, we see clearly how advantageous it is to make the projectile present a surface oblique to the direction of the forward motion, or motion of translation.

Nevertheless we must particularly observe, that, in this case, the resistance of the air pushes the projectile and causes it to deviate in the direction opposite to the inclination of the surface. Now, in order that this deviation should not incline the projectile from the right line of its motion, its fore part must be so fashioned that the resistance experienced by the projectile in any direction should be counterbalanced by an equal resistance acting in a contrary direction. This takes place in projectiles whose fore-surface is conical, when the axis of the cone coincides with the direction of the motion (fig. 101).

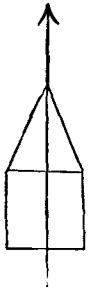


Fig. 101.

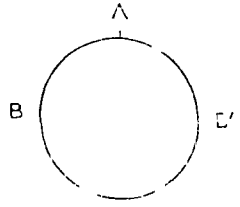


Fig. 102.

The same would take place with a spherical projectile so long as there were no motion of rotation about any other axis but that parallel to the direction of flight. But, if there be a motion of rotation in direction BAB′ (fig. 102), the motion of translation being towards A, this rotation will

increase the rapidity with which the side BA impinges on the molecules of the air, and diminish that on the side AB′. The result will be a greater lateral force impressed on BA than on AB′, and a drift towards the side B′. When the axis of rotation of an elongated projectile ceases to be parallel to the direction of flight it is affected in precisely the same manner, causing, as stated in the text, a drift in the same direction as the rotation of the projectile, or of the grooving of the rifle from which it has been discharged.

CONCLUDING LECTURE.

Rifle Systems—Small-bore Rifles—and Breech-Loaders.

I. In the preceding Lecture, which may be considered the last of the prescribed musketry series, we have endeavoured to explain the action and general principles of rifling with reference to the Enfield. We now propose to give, in conclusion, a short account of some other rifle systems, together with a few remarks on rifles of smaller bore.

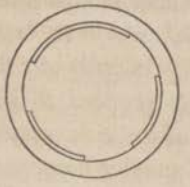
The first and primitive idea of rifling was, as we have seen, to get a grip on the shot, by which the vertical rolling over and over, or upsetting, which it acquired when projected from an ordinary smooth-bore, might be altered into a fixed axial rotation.

Differences of accuracy, and more or less fouling, were soon found to be attendant upon different plans of grooving and channeling, but long practice and study were required before the best method of rifling could be determined.

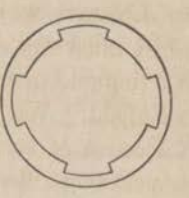
II. The result of innumerable ideas and experiments has been to produce the various methods of rifling which characterise the guns of our best manufacturers. Our space will not allow us to discuss this vast number of contrivances, but we may resolve them all into three distinct classes, which may be briefly described as follows:

Class 1. The groove or Enfield system is that of not only the most ancient but also the most prolific of the family of rifles, for in all countries, and in every era, do we find rifles on this principle, with the most capricious variety of depth and number of grooves. These, as we have already seen, were very numerous in the early rifles, sometimes even upwards of a hundred; but numerous grooves are now quite out of fashion, except in the Armstrong gun, and the number now rarely, if ever, exceeds seven. It need hardly be added that they are never less than two. We subjoin

here a few specimens of the most recent modifications and special varieties of this class.

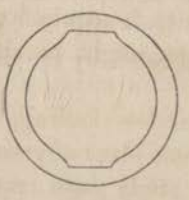


Enfield.
Fig. 103.

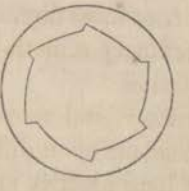


Turner.
Fig. 104.

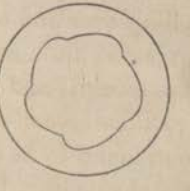
Edge.
Fig. 105.



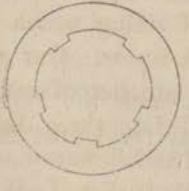
Jacob.
Fig. 106.



Rigby.
Fig. 107.



Hans Busk.
Fig. 108.



Five-grooved.
Fig. 109.

"Round"
or Concentric.
Fig. 110.

"Circular"
or Excentric.
Fig. 111.

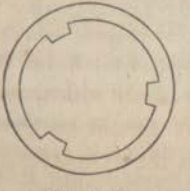


Fig. 112.
Three-grooved.

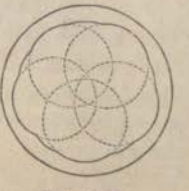


Fig. 113.
Boucher,
or Lancaster.

III. Class 2. The elliptical bore, which was first adopted in this country by Mr. Lancaster. The cardinal feature of this rifle is that the bore of the barrel is smooth, and instead of being circular is cut into an ellipse or oval. On being expanded by the force of the powder, the bullet, which is the same as the Enfield, is forced into the form of the ellipse, which performs the function of grooves, rifling the projectile and imparting to it the spiral motion. In fact it may be called a two-grooved rifle in disguise, for if we conceive a rifle with two grooves, as in the figure, to have the edges of its grooves pared off, an oval bore will at length be the result, and this alteration is indicated by the dotted line in fig. 114.*

Fig. 114.

When first brought out, in 1851, with the Pritchett bullet ·568-inch diameter, the turn was one-fourth in the whole length of the barrel.

Minor axis ·577 } freed at breech ·003.
Major axis ·592 }

* The originality of Mr. Lancaster's invention has been questioned; a certain Captain Berner having, it is said, submitted an elliptical bore musket for inspection and trial to the Royal Hanoverian Commission appointed for that purpose. Such assertions are very common, and, without an examination of the gun in question, it is impossible to admit the claim of priority. Certain it is, however, that Mr. Lancaster never heard of the gun in question, and that previous to his own patent for the invention no one ever adopted or carried into practical use the system of the oval bore.

The freeing at the breech in the Lancaster corresponds with the progressive grooving in the Enfield, and it is considered an advantage where the expansion of the bullet has not been completed at the first moment of discharge, diminishing also the liability to strip in the bullet.

The Lancaster method of producing all the results of rifling is certainly a most ingenious invention, perhaps surpassing any modern improvement in the rifle.

In this rifle we have the simplest modification of the principle of rifling. The degree in which fouling is produced is a main criterion of the value of a system of rifling: it being evident that a gun without grooves must afford less lodgment for fouling than a gun with grooves.

IV. The Enfield has had as yet effectively but one rival of the same calibre worthy of the name, namely, this Lancaster rifle. It appears that during the winter of 1853-1854 the Lancaster 1851 pattern was twice brought into competition with the Enfield and other rifles at Hythe, and according to the report of the trials it was found to exceed all others, both in accuracy of firing and facility of loading. Unfortunately the bullet exhibited a decided tendency to "strip," and, this having been clearly established, the rifle was wisely rejected.

V. The very recent report however of the Ordnance Select Committee, relative to the best description of rifle small arms for military service, has tended to place the matter on a different footing, and opened serious questions as to the retention of the present small arms used in the service.

Incontestable as are the merits of the Enfield rifle, still it could not be supposed that our admirable national weapon had attained the "finality" of perfection. The experience of several years has shown that beyond the range of about

600 yards the Enfield arm ceases to be a weapon of precision, and the question whether, the calibre remaining the same, certain advantages might not accrue from modification of rifling and its pitch, was definitely put by the War Office to the Committee as follows :—

"That the Committee should consider whether the Lancaster oval-bore rifle possesses any superiority over the Enfield rifle, and whether they would recommend any extension of its use?" Their reply is decisive.

A strict but impartial comparison on all points connected with military efficiency establishes the superiority of the Lancaster rifle. Should it therefore be decided to retain the present Enfield calibre (and in the absence of any data of their own as to the value of the polygonal system applied to this calibre), the Committee are of opinion that the adoption of the Lancaster system of rifling will be attended with considerable advantage to the service, more particularly as it can be accomplished without necessitating any change in the present service ammunition or increase to the present cost of supply.

VI. Such is the final verdict in favour of the Lancaster, and certainly no other could apparently be delivered after the following results of the trial :—

Having then (so runs the Report) carefully weighed and considered the relative advantages of the Enfield and Lancaster systems applied to large calibres, and adapted to one and the same ammunition, viz. bullet 530 grains—diameter 0·55—wood-plug, powder 2½ drachms—J² cartridge service—lubrication, pure wax, the Committee are led to the following opinion :—1st. As regards precision when clean, the Lancaster rifle has the advantage. 2nd. As regards precision when foul, the Lancaster has a decided advantage. 3rd. As regards non-tendency to accumulate fouling, the Lancaster is considerably superior. After firing 100 rounds the Enfield loaded roughly, hard fouling being deposited in patches on the surface of the bore, and the shooting was wild; whilst the loading of the Lancaster continued easy throughout, and the shooting had scarcely deteriorated. 4th. As regards simplicity of management, the Lancaster has the advantage, a smooth barrel being more easily cleaned

than a grooved barrel. 5th. As regards penetration, about equal (average penetration at 30 yards in half-inch elm boards placed half an inch apart), Lancaster 12·00, Enfield 11·40. 6th. Rapidity of fire, equal. 7th. Total weight of arm, the same; weight of barrel, the same as the Enfield.

	Lancaster. Feet.	Enfield. Feet.
8th. Initial velocity, arms being clean .	1,234·9	1,248·6
With foul arms, after firing 1,020 rounds, the initial velocity was .	1,211·8	1,157·3
Showing the effects of fouling loss .	23·1	91·3

9th. As to flatness of trajectory, the Lancaster has the advantage. 10th. Cost of manufacture about equal.

In the elliptical system the frictional surface is considerably reduced. Theoretically, when loading, the bullet with its envelope of paper and wax should touch only at two points,—but practically a certain amount of bearing surface must exist between the bullet and the sides of the barrel. In the Enfield rifle the amount of bearing surface and consequent resistance to the bullet is considerably greater; and finally, the Lancaster with its smooth-bore will escape the damage inflicted by the platoon exercise, at all events as much as is possible in such an assault against the integrity of the rifle.

VII. It should be stated, however, in justice to those who framed the report of 1854, that the Lancaster rifle which won the encomiums just enumerated differs materially from its predecessor of that date. In the 1862 pattern rifle as described by Mr. Lancaster, with a ball ·550, there is one whole turn in the barrel—

Minor axis ·565
Major axis ·580 } freed at breech ·003.

From this it will be seen at a glance that the 1851 pattern has undergone an important modification. An entire turn is given in the length of the barrel instead of

merely one quarter; and, whereas in the previous rifle the diameter of the bore was ·577 inch, it is now ·565, or ·012 less than the former rifle or the present Enfield, thus practically involving a minute reduction of the bore, a feature perhaps of considerable importance in the production of the results, for, as the bullet since 1851 has been reduced ·018 in diameter, while the Enfield rifle has undergone no corresponding change, the conditions are left in favour of the Lancaster.

But this by no means detracts from the merits of the weapon, for with the same ammunition as used with the Enfield it has established its superiority as a military arm, especially with reference to the important points of fouling and facility of loading.

VIII. The fouling of a rifle spoils its shooting, and hinders and finally prevents its loading. Bad shooting and incapability of being loaded are fatal defects on the battle field, and it would be useless to train men laboriously as marksmen and sharpshooters if the costly weapons we supply to them would only fire ten or a dozen shots with precision.

It is because the Lancaster rifle is less liable to foul than any other small arm that we have reason to be gratified at its last unmistakeable success; for the delicate weapon that in accomplished hands projects its bullet with unerring accuracy might not be best adapted to the rough usage of war, and it might have been that a less accurate but more enduring weapon would have been more suitable for practical use. It is, however, satisfactory that the truest rifle in match shooting is the simplest and best for war, and that our soldiers will be eventually armed with a weapon that will fire its last shot in the fight with all but as much precision as its first.

Of the Enfield rifle the Committee admits as an excuse for its shortcomings that it was introduced into the service when comparatively limited experience had been acquired in this country with respect to elongated rifle bullets, and when no fixed and generally accepted principles had been established as to rifling small arms. The Enfield rifle as at present made fails in precision at distances above 600 yards, and any attempt at improving it by increasing the spiral increases the tendency to foul, and thus mars its efficiency as a military weapon. Another defect is the large frictional surface presented to the descending bullet by the broad lands between the grooves, necessitating the use of a smaller bullet than the capacity of the bore in order to effect the loading of the piece.

IX. With regard to variations of rifling, experiments proved that barrels like the Enfield, but having four grooves instead of three, gave better results than the regulation Enfield. The Committee found, moreover, that, as regards mere accuracy of shooting, considerable advantage accrued from an increase of pitch from one turn in 78 inches, present regulation, to one turn in 48 inches. The result however is not a clear gain. Present experiments, observe the Committee, show that the precision "of the Enfield rifle when the arm is clean is capable of considerable improvement by a combination of increased twist with five grooves, but that, under circumstances of firing continued beyond 150 rounds without cleaning, the loss in precision due to the increased fouling is such as to reduce its precision almost to a level with that of the present service Enfield."

The Committee does not recommend that the Enfield in any of its modifications should be retained. They state their preference for the Lancaster or oval-bore in a manner

so emphatic that it seems hardly possible that the Enfield can be much longer retained as the arm of the service. Should this be the case, the Enfield will have had a short but not inglorious existence. If it cannot exult with the immortal shade of Brown Bess in having added a hundred and one inscriptions to our regimental colours, it can at least boast of having turned the tide of war in our favour at Inkerman, Lucknow, Pekin, and New Zealand, in the short space of about eight years.

X. Class 3. The Polygonal system as embodied with more or less prominence in the Whitworth, Westley Richards, and Henry rifles, together with some others, will in future always be associated with the name of Mr. Whitworth, for,

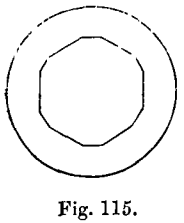


Fig. 115.
Whitworth.

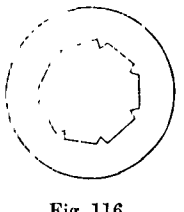


Fig. 116.
Westley Richards.

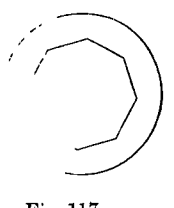


Fig. 117.
Henry.

although the principle of the system is by no means new, it had fallen into such disuse that it may be said to have become virtually extinct till revived by the genius of this eminent machinist.

In his experiments with small arms, commenced in 1854 at the suggestion of the late Lord Hardinge, then Commander-in-Chief, Mr. Whitworth has perhaps done more than any one else to establish on a scientific basis the relative harmony that should exist in the elements of a rifle between the cylinder, the grooves, and the bullet.

Commencing with the greatest weight of bullet that it is

possible, on account of recoil, for a man to fire from his shoulder, and investigating what advantages in each direction may be obtained, compatibly with the conflicting considerations, Mr. Whitworth established to his satisfaction that the best length of a projectile is about three diameters, and, the Government having for military reasons fixed 530 grains of lead as a maximum weight for the musket projectile, he arrived by calculation at the conclusion that the bore of the musket should be about ·45 in. or a little under the half-inch. Working on this datum, he constructed a rifle possessing a degree of accuracy never before attained.

The best Birmingham gunsmiths have never reached a higher standard of approximation to the required diameter of a barrel bore than the 350th of an inch; and in the Enfield the variation allowed from the standard gauge is 1000th of an inch; whereas Whitworth attains the 5000th of an inch. Mr. Whitworth proves the possibility of measuring sizes mechanically up to the millionth of an inch, and says that up to that time, 1854, no steps had been taken to test by means of different gauges the accuracy of the interior of gun-barrels, upon which the correctness of the fire depends. Applying his delicate tests to the most highly finished barrels hitherto produced, he shows that they are very false, and contain inequalities that cannot but detract greatly from their precision of fire. In some the bore was found to be conical in one direction, in some in the opposite, and all were more or less irregular.

XI. The bore of his rifle is hexagonal. A section of the barrel is represented in fig. 119; the rifling has a twist of one turn in 20 inches, so that the ball makes nearly two turns before it leaves a piece 39 inches long. The diameter

of the hexagon from side to side across the surface is ·451in. and across the angles which represent the grooves in an ordinary rifle (Class 1) ·503 in. So that, instead of consisting partly of non-effective lands and partly of grooves, the interior of the barrel consists of effective guiding surfaces throughout.

Fig. 118.

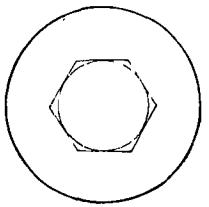


Fig. 119.

Fig. 120.

The pickets or bullets are either of the form shown in fig. 118 or as shown in fig. 120. Supposing a bullet of the cylindrical form (fig. 118) to be fired, when it begins to expand it is driven into the angles of the hexagon. It thus adapts itself to the course of the spiral, and, the inclined sides of the hexagon offering no direct resistance, expansion is easily effected. While the ordinary grooved rifle depends upon the expansion of the soft metal projectile, in the hexagonal system rifling may be effected independently of expansion, by making the projectile of the same shape as the interior of the barrel, fig. 119.

This projectile may be used naked, and be made of any degree of hardness. When it enters the gun it bears upon a certain portion of each side of the hexagon, and when it comes out it bears on the opposite portion,—by easing off,

therefore, the half of each side on which the projectile bears as it enters, the bullet is easily rammed down; the other halves of the sides are left to preserve a full extent of bearing surface as it comes out, by which all windage is stopped, and at the same time its concentricity with the bore is maintained.

The expansion principle may thus be combined with an easy mechanical fit, so that a projectile of metal harder than lead, as an alloy of lead and tin, may be used, which, while it loads easily, will expand sufficiently to fill the bore and give more than double the penetration.

XII. By the polygonal bore and rapid pitch, to which the form of the bullet accurately conforms, the projectile can be increased in length so considerably as to secure space for converting it into a shell if necessary; and, it being possible to use metal of any degree of hardness, its form and strength can be adapted exactly to the work it has to perform.

XIII. Mr. Whitworth's rifle, as above described, was tried at the School of Musketry at Hythe, and compared with the Enfield rifle. From this experiment the efficacy of the Whitworth, as compared with the Enfield, was as 20 to 1. At 1,800 yards the Whitworth drove its bullets into the target, while at 1,400 yards the Enfield made no hits. The Whitworth at 1,100 yards, as regards accuracy, was nearly on a par with the Enfield at 500 yards; and, when both were fixed at 500 yards, the Whitworth was superior in the proportion of 3 to 1.

XIV. The Ordnance Select Committee, in one of its reports, remarks, that

> The increased penetration of rifled projectiles is in a far higher ratio than theory would assign them. It is plain, therefore, that we must look for some other cause for this than their superior *vis viva*,

and this is furnished by their rotation on their longer axis. The 6-inch projectiles leave the muzzle of the gun spinning at the rate of about sixty-three turns per second. It is not probable that this rate diminishes as fast as the motion of translation. It will be very little reduced in three or four seconds, or at 1,032 yards, and *must materially aid penetration.*

XV. It would therefore appear that increased rotation gives increased penetration, probably on the same principle as the common auger; and so, if this assumption holds good with a projectile rotating sixty-three times in a second, how much more will it do so with the Whitworth bullet, which rotates at the rate of 750 revolutions per second? Let the results in this respect speak for themselves; the Whitworth projectile (fig. 120) with the regulation charge of powder went through 33 half-inch planks of elm, and was only "brought up" by a solid oak bulk beyond. The Enfield could not get past the thirteenth plank.

With a barrel 29 inches long, ·45 bore, with one turn in 20 inches, which Whitworth proposed as the best pattern for a military small arm, he found no difficulty in penetrating a wrought-iron plate 6-10ths of an inch thick, or cutting a core out of a piece of solid timber half a foot thick.*

XVI. Such, in substance, was the result of the trial of this rifle in 1857. Since that day it has had to hold its own in many a contest, for, like everything that acquires a sudden pre-eminence, it has had to encounter assailants and detractors in divers forms and from many quarters. It has been "sat upon" by two committees, and in addition has passed no end of "comparative examinations." In all these

* The question of drilling holes in the 4-inch and 5½-inch breast-plates of iron-clad ships is at once solved, as has recently been demonstrated, by the application of these principles to artillery,—but without avail, so far as our Admiralty is concerned.

it has topped the list; and when we hear of it making, in the unaided hands of one man (Captain Heaton), ten consecutive bull's-eyes at a distance of 1,000 yards, and in those of another (Captain Rawson) seven consecutive bull's-eyes at a distance of 1,100 yards, we hardly know whether most to admire the rifle or the man.

A weapon which in expert hands will make good practice at 1,400 yards, and the range of which can be very easily helped by a telescope, if necessary, gives the *coup de grace* to our old smooth-bore field batteries.

At the Alma it would have silenced the Russian guns, or driven them from their position, rendering unnecessary the rush of the light division, with the heavy loss of life consequent thereon. Nor during the siege of Sebastopol would the rope mantelets of the Redan and the Malakhoff have given much protection to the men working behind the embrasures.

XVII. It is very doubtful, however, whether this now famous weapon would not have remained comparatively neglected and unknown had it not been for the spirited leaders of the Volunteer movement, who organised a National Rifle Association with the view of annually eliciting the best rifle and the best man to wield it. And it has been mainly in the field thus opened for it that the Whitworth has, at each successive meeting, proved its surpassing excellence.

XVIII. But it must not be supposed that Whitworth has been alone in his efforts to produce a perfect rifle; far from it; ever since and even before the stimulus given to rifle-shooting by the Volunteer movement and the National Rifle Association, a host of rivals have contended, and not unworthily, for the blue ribbon of the rifle ring.

Amongst these is the Henry rifle (fig. 117), the bore of

which is heptagonal, with a rib or beading in each of the angles, thus presenting fourteen tangential points or surfaces for the projectile to bear against, which is supposed to give it a uniform steady motion in passing out of the barrel; next the rifles of Messrs. Edge, Turner, Kerr, Daw, Parsons, Boucher, and many others.

The superiority of the Whitworth rifle over these appears however to be conclusively decided to the satisfaction of the Ordnance Committee, who report in November, 1862, that "they think it only just to Mr. Whitworth to acknowledge the relative superiority of his small-bore rifle, even as a military weapon, over all the other rifles of similar calibre that have been under trial:" and, in speaking of the performances of rifles of the same bore by other makers, they say, that, "in every instance where there has been any pretension to special accuracy, they have copied to the letter the main elements of success adopted by Mr. Whitworth, viz., diameter of bore, degree of spiral, and large proportion of rifling surface, and it is not probable that any further modifications that might result from the question being now thrown open to the gun trade would be attended with any practical advantage."

XIX. The next question that will engage our attention is one that has been for many years mooted amongst military men, and all interested in the efficiency of our armaments. It is this: "Whether, in consequence of the advantage which a rifle of small bore appears to possess over the Enfield rifle, it is advisable, taking into consideration all military reasons, to adopt a rifle of smaller bore as the armament of any portion of the army, or even the entire service?"

Various reasons are advanced for replying to this question in the negative; and we shall now briefly consider these objections.

XX. First in importance is, of course, the objection of the Ordnance Committee recently put forth, and prefaced by the following significant sentence:

The Committee are of opinion that, as the present system of musketry instruction is calculated to produce ere long a very high standard of shooting throughout the army, the introduction of a weapon of great precision at long ranges would materially increase the general efficiency of the infantry, and place it in a better position to keep down the fire of the rifled artillery of the present day.

Then follows the objection, which will scarcely be endorsed by the great jury of riflemen who have so long used the small-bores, especially the Whitworth:

Although the reduced bore has shown a great superiority in precision over the large calibre, and in some respects exhibited a greater suitability to be employed as a military arm, yet the wear that takes place in the percussioning is so considerable, that the rifle in a very short time is rendered unserviceable.

In the course of these experiments, and before 500 rounds had been fired from any one of the small-bore rifles, eleven hammers had been broken by the force of the gas escaping through the nipple.

The threads of the screw in the nipple lump had in most cases been blown through, and in one instance after 1,500 rounds the nipple lump cracked to an extent of 0·7 inch, rendering the arm unserviceable.

This wear may, however, be prevented to a certain extent by bouching the nipple-hole with platinum or copper, and by a very careful fitment of the nipple into its bed; but the Committee are satisfied, from the experience they have had, that no amount of precaution is likely to be effectual in preventing the very rapid wearing out of the small-bore rifle in this respect.

In a case of this kind it is only fair to listen to what the parties concerned have to say in their own defence. Now Mr. Whitworth states positively that such accidents as the Select Commitee describe have never happened to the Whitworth rifle, and he adds, that "all that is requisite to

prevent the breaking or blowing back of the hammer, is to 'bouch' the nipple with platinum, which costs only sixpence.". Our own experience certainly corroborates this statement, and we have seen fired, and fired ourselves, thousands of rounds with the Whitworth rifle without a single accident of the kind mentioned in the Report of the Ordnance Select Committee.

The only explanation we can give of this discrepancy in the evidence is, that the Whitworth small-bore rifles used in the trials at Woolwich by the Ordnance Select Committee last year were made at the Royal Small Arms Factory at Enfield, and had the common plug or tailpin breech, whereas in the "Whitworth Match Rifle" (manufactured at Mr. Whitworth's factory) a patent breech is adopted, arranged in the manner shown in the figure.

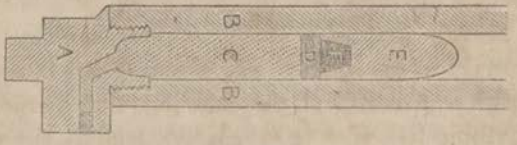


Fig. 121.

This breech has the advantage of being case-hardened, thus reducing the liability to wear and corrode from the action of the gunpowder; in some respects, however, the common plug or tail breech is considered superior in a military arm, as it can be cleaned with greater ease.

XXI. The next objection is the change of ammunition involved in the adoption of the small-bore rifle. It is said that the increased length of the cartridge would render it liable to break in the pouch. This, however, has been practically confuted by the use in the Cavalry, for some time past, of small-bore cartridges with the Westley Richards carbine, without any result of the kind mentioned.

At all events this difficulty, if it exist, could be met by a slight modification in the proportions of the cartridge-box.

XXII. As to the other objection, that it would involve the necessity of having two sizes of ammunition in the Service, this evil, if such it can be called, would be merely of a temporary character. Besides, if there were not more than two kinds of musket ammunition required, and these two kinds were totally distinct in colour, shape, and general appearance—any man capable of distinguishing black from white, or round from square, could scarcely make a mistake between the two.

XXIII. The next difficulty raised is of so speculative and imaginary a character, that we should hardly consider it worth while to notice it here, were it not for the fact that it has been strenuously urged by many of those who are opposed to any diminution of the bore of the rifle.

It is gravely asserted that any calibre less than that now in use would be too small to kill a man—that it requires a bullet with a diameter of ·55 inch for that purpose—and that anything less, such as ·45, is too small for the work !

But, even admitting the validity of this objection, surely the great increase in the number of *wounded* men resulting from the greater accuracy, flatter trajectory, and deeper penetration of the small bore, would more than compensate for the very doubtful defect in question.

We have already shown that the trajectory of the Whitworth is about 40 per cent. flatter than that of the Enfield; and, as to penetration, that it has a relative advantage of 35 to 12 : in other words, if at a distance of 500 yards the *Enfield* bullet would go through two men, the *Whitworth*, at the same distance, would pass through six men.

Moreover, we have the highest authority for stating, that, judged from a purely surgical point of view, the number of

men put *hors de combat* in action by the introduction of a weapon such as the *Whitworth* small-bore would be probably enormously increased; and that, although the increased velocity of the *Whitworth* projectiles would doubtless make them penetrate and perforate directly the various parts of the body, instead of coursing round, glancing off, or being arrested in their progress; yet, as regards flesh-wounds, and they fortunately form a large majority, the effects would be less serious than those caused by projectiles with less velocity. The average length of time, however, required for the cure of such wounds, when no important structures are involved, would be seven or eight weeks; and for this period the soldier would be removed from active service.* Thus, curiously enough, it would appear that the interests of humanity and the general object of war would both be promoted by the adoption of small-bore rifles.

Undoubtedly, to "stop" an elephant, or to bring a rhinoceros or grizzly bear upon his back, requires a tolerably big plug; but common experience demonstrates, that a very slight wound is sufficient to render a man useless for all purposes of offence and defence.

XXIV. In the course of these observations we have referred mainly to the Whitworth rifle; but we are anxious to have it understood, that we have done so simply because it represents a class of improved small-bore rifles; and not with any desire to assign to it the attribute of "final perfection."

In the very Report which we have been considering, it appears that in one or two instances where wax was used as the sole or chief ingredient of the lubricant, or where the

* Deputy-Inspector General S. T. Longmore, Professor of Military Surgery.

competing rifles were fired in a partially fouled state, the *Whitworth* was excelled by the *Lancaster* small-bore; although it must be admitted that the difference in every case was very slight. On the other hand, it is certain that hardened mechanically fitting bullets or shells can be discharged from the hexagonal bore with the most destructive effect.

But, whatever doubt may remain to which rifle we shall award the palm of superiority, it is sufficient perhaps to know, that we have in either a small-bore rifle whose trajectory, accuracy, and penetration are vastly superior to the present service weapon; while the latter is nearly as costly as one of the best construction.*

With the whole intelligence of the country, civil as well as military, directed to the subject of rifles and military weapons, it is most improbable that we can long retain what is admitted to be only second best.

It would be unwise, perhaps, to discard at once so good a weapon as the present *Enfield* rifle; but, having discovered a better, we might, after the new guns have had a sufficient practical trial, gradually introduce them into the service, in proportion as the present weapons require to be renewed. But, apparently, the change is already begun. We rejoice to hear that at least 8,000 rifles are at the present moment ordered to be made at Enfield according to the *Whitworth* pattern; and all the regiments of the Rifle Brigade are to be supplied with them as a preliminary measure.

XXV. Assuming, then, that we have secured the best existing gun-barrel—a weapon with a range, trajectory, and power of penetration leaving little further to be desired—it may be said, "Now, surely, you are satisfied!" Not

* The Whitworth rifle can be produced at an additional cost of 15*s.* per rifle over that now in use.

so; for, granting that the new weapon has all that seems requisite at the present moment as to precision, we humbly submit that its efficiency, both for attack and defence, is capable of being vastly increased by the adoption of a system of breech-loading, thus getting rid of the present slow, clumsy, injurious process of muzzle-loading, on the obvious disadvantages of which we need not enlarge.

We are well aware that high authorities have from time out of mind denounced the breech-loading principle as improper in the fire-arms of infantry, "because," it is said, "the soldier, being enabled to fire more rapidly, would squander away his ammunition, and find himself bereft of it at the moment when most needed;" but this is an assumption quite akin to the objections raised against every other improvement in the advance of art and science.

Now, Prussia has adopted the breech-loader generally; France is decidedly meditating the same "idea;" and it may turn out that in this matter, as in so many others, we shall have to follow in the wake of our great rival with that haste and spasmodic effort by which, fortunately, we have been enabled hitherto to escape the consequences of past neglect and delay.

XXVI. Let us, however, examine the alleged argument against the use of breech-loaders by the infantry in general. It must be admitted that a badly disciplined or thoughtless soldier so armed would, perhaps not unfrequently, especially at the beginning of an action or campaign, fire away his ammunition too quickly with reference to the supply at command; but then much the same may be said of our present Enfield muzzle-loader. In fact, I have seen this more than once. But would any one on that account consider it expedient to return to the very slow mode of loading a rifle with mallet and heavy rod, in vogue at the beginning

of the last century? The possibility of *abuse* is generally a weak argument against *use* in anything; and it happens most appositely that the very same argument might have told against the use of the long-bow. One of the strongest arguments for the retention of the long-bow in the olden time was its superiority in point of celerity of fire over the cross-bow and fire-arms; for, "from its construction and greater facility of handling, it gave to the archer the power to produce a far more rapid succession of shots—a faculty which was always controllable by those who possessed it, and always available at need."* Moreover, from the time when the English long bow was at length superseded by fire-arms, down to the present day, our constant effort has been to create a weapon which should unite the celerity of the bow with the precision of the rifle.

XXVII. The advocacy of the breech-loading principle is not "a new-fangled idea"—the impracticable conception of mere enthusiasts; for it was attempted with the earliest specimens of fire-arms, and only abandoned for the time owing to the want of the mechanical skill which, in our day, has effectually overcome the chief difficulty in the way of our forefathers, namely, that of thoroughly closing the breech, so as to prevent an escape of gas. Yet we are to be told, that, after all these long years of untiring endeavour, when the idea sown five hundred years back has borne its fruit, we may not reap the benefit.

If we ask why this should be so, the only answer we can obtain is, that the English army of the present day is not worthy to be trusted with the same power which was possessed by the victors of Cressy, Agincourt, and Poictiers! Such is the absurd conclusion of the argument against the general use of breech-loaders in our army.

* Deane, "Manual."

XXVIII. If there be one point in which all who are acquainted with the tactics of the battle-field agree, it is the never-failing success resulting from a superiority of fire at a given point and time. Now, what could be more conducive to such a result than the use of a weapon which, on an emergency, could pour in a rapid succession of deadly missiles on the enemy? Again, with breech-loaders our skirmishers would be able to load noiselessly, lying on the ground, so that at 300 yards a tuft of grass or small stone would be sufficient to screen them from the enemy.

The breech-loader has numbered amongst its supporters many distinguished veterans in France who qualified in the battle-fields of Napoleon—men whose minds were less subservient to the past and more prescient of the future. It has been advocated by Brandt, the distinguished soldier and writer of Prussia; by the great comrade in arms of Prince Eugene and Marlborough, Field Marshal Saxe—the well-known author of the "Maxims on the Art of War;" and, recently, by the veteran French General Rémond, who, in a pamphlet entitled "*Tactique appropriée aux Carabines se chargeant par la culasse*,"* writes, that—

In skilful hands the breech-loader will nearly rival the arrow in rapidity of fire. This simple element of its condition will immensely modify the tactics of the battle-field. The infantry armed with

* General Rémond thus prefaces this pamphlet:—"En France et en Angleterre on a inauguré les carabines qui se chargent sans maillet, et, en Prusse, le Zünd-nädel qui se charge sans baguette. Persuadé que ce mode de charger les carabines par la culasse sera adopté aux premières guerres, nous lui avons approprié les diverses parties de la tactique, mais nôtre but, quand a présent, n'étant que d'attirer l'attention de nôtre Gouvernement sur la gravité de ce progrès, nous nous bornons à envoyer aux personnes compétants le sommaire des études que nous avons faites sur cette transformation indispensable."

breech-loaders, and readily "forming fours," will dispense with the formation of squares, which checks the advance, and renders it so vulnerable to artillery. With breech-loaders effectual fire of the deadliest kind could be delivered with a rapidity that nothing could withstand, viz. in four ranks, and even in five, the first lying, the second sitting, the third kneeling, the fourth and fifth standing.

Again, in an Essay on the progressive History of Fire Arms by a recent writer, we find the following remarks on this subject:—

Space will not permit the discussion of all the tactical advantages that would result from the adoption of breech-loaders, which, however, will be obvious to those most concerned in the defence of the nation; but this is certain, if all our forces become armed with breech-loaders, and become skilled in their management, every hundred men will be equal to a thousand for defence against invasion. If we cannot have an adequate standing army, and a thoroughly efficient militia, let us arm the former, at least, with breech-loaders, each of which will dispense with the cost of nine men, and so pay for itself, by *saving money;* for the very best breech-loading rifle could not cost more than 18*l.*, which is less than the soldier's annual pay.

Deane in his excellent work on Fire Arms thus summarizes the advantages of breech-loaders:—

The rapidity of a multiplied fire at will, once more attainable, must and will become a new and powerful element of success in battles; and its value will yet be established as thoroughly as, in the Crimean War, was that of the improved faculties of range and precision in the muzzle-loading musket.

Hitherto the most formidable opponent of the light infantry has been cavalry. After the delivery of their first fire light infantry have hitherto been comparatively defenceless; for before being able to reload they have been pierced with the lances of the horsemen whom their bayonets could seldom reach.

Breech-loaders would be of incalculable advantage to the foot-artillery for the defence of their batteries; to the

sappers and miners and trench-guards, to repel surprises whilst carrying on their works; as well as for the defence of baggage trains; that of posts, bridges, defiles, &c.; and lastly, against the hitherto crowning charge of infantry with their bayonets at the hip. Such an amount of fire delivered coolly and steadily by a two-line formation of light troops armed with breech-loaders, would be destructive of all order among the assailants for effective attack.

The possible waste of ammunition seems, for the reasons above stated, a most inconclusive argument against the general introduction of breech-loaders; but Mr. Westley Richards suggests that this liability might be prevented by causing the men to advance rapidly without firing a shot until within 300 yards of the enemy; or by arrangements being made for bringing forward increased supplies of ammunition. In the former case, he quotes the action of certain Volunteers armed with breech-loaders. After doubling down from 700 to 300 yards, they commenced firing from the knee from the 300 to 50 yards; and each man put 54 shots into the target out of 59 rounds per man fired in the space of 18 minutes. "There can be no doubt," he says, "as to the comparative value of the breech and muzzle loaders. With the breech-loader rather more than two shots can be fired for one with the muzzle-loader. The soldier advances more rapidly, as he is not delayed by loading; and when loading he is in a good position both for self-defence and rapid firing."

But in addition to mere opinions we may adduce the inexorable logic of facts. In one part of the hard-fought battle of Ilstedt, the Danes were opposed by German skirmishers armed with the Prussian breech-loading needle-gun.

The enemy, says the Danish General Krogh, under cover of a bridge, fired with pointed bullets at a distance of 100 and 150 yards. It was in vain that our cavalry charged and our infantry attempted

to advance. In less than an hour we suffered great loss. The General in command was struck down; the chief of his staff was wounded; and several other officers were killed and wounded.

The terrible effect of the Prussian breech-loading rifle may be gathered from this report, even if it had not before been proved, during the same struggle, in the bloody battles of Kolding and Frederica.

Notwithstanding such results, the statement has been circulated by the opponents of the breech-loading principle, that the Prussian needle-gun was a complete failure, entailing the abolition of file-firing in the Prussian ranks and other disadvantages; and that it was on the eve of being abandoned as the arm of the service; but a striking contradiction to such reports was afforded during the Crimean War when 1,000,000 thalers or £200,000 were voted in excess of the preceding year's expenditure, to enlarge the manufactories of the needle-gun.

It would be useless here to give an account of the different systems of breech-loading from the supposed first application of the principle to small arms by Henry II. of France, in 1540. Systems of breech-loading are so numerous that it would fill a volume of no small size to describe them. Such are the *Fusils of Marshal Saxe*, *Tourette of Saint-Etienne*, *Pauly*, *Robert*, *Le Roy*, *Lefaucheux*, *Charroi*, *Jh. Montigny*, *Pierre Montigny*; the *Norwegian* and *Swedish*, used in the Marine; the *Prussian needle-rifle*, *Clerville*, *Treuille*, *Thomas*, *Riera*, *Prince's*, &c.; *Musketoon-Lepage*, *Gilby's*, *Gillet of Liège*, *Potet*, &c. &c. The United States have, in like manner, many varieties of breech-loading arms; among them we may particularise *Sharp's*, *Burnside's*, *Merrill's*, *Jocelyn's*, *Maynard's*, and *Colt's*.

We shall therefore restrict ourselves to giving a short description of the two breech-loaders which now vie with

each other in claiming to be considered the best for adoption in our service as a military weapon—that of Mr. Westley Richards of Birmingham, and that of Mr. Mont Storm, Federal States of America.

We shall first take Westley Richards's patent breech-loading rifle.

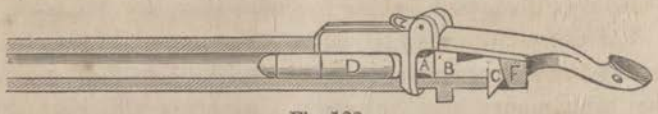


Fig. 122.

Fig. 122 represents a section of the breech-loading parts. A is a gun-metal plunger which enters the breech end of the gun, B is a solid iron block with an inclined plane at the back C. There is a second inclined plane at the point E, which throws the block B back into its place, and makes it fit close against the end of the box F, which is also undercut, to fit the inclined part of the block B at the point C. The block has a sliding motion to allow this action to take place. By this it will be seen that the greater the pressure on the block and plunger the safer the part becomes, the inclined plane holding the lever firmly down in its place. D represents the cartridge.

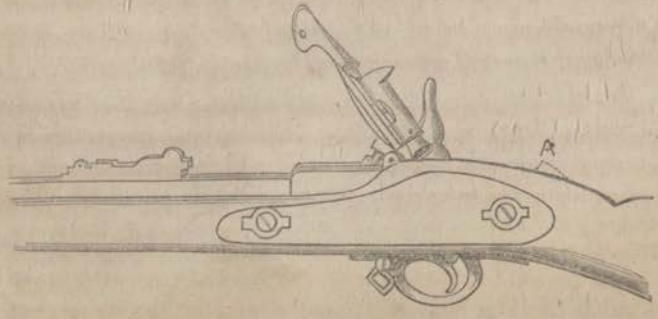


Fig. 123.

Fig. 123 exhibits the rifle ready to receive the charge, and shows how the breech is raised to load the gun, the junction being behind the cartridge. When the rifle is closed a small lump marked A in fig. 123 is the only projecting part; in all other respects the gun has the appearance of an ordinary rifle gun, and for safety, simplicity, and rapidity of loading, it appears hardly probable that any improvement of importance can be made. The barrel is that of the Whitworth in every respect, save in the number of sides, which are eight instead of six; hence the bore is octagonal. With the rifle proposed by Mr. Richards as a service arm the bullet to be used will be the same in shape as that in fig. 122, and will weigh 500 grains, "certainly not more and probably less;" the charge of powder to be 80 grains, equivalent to 2·92drs. The weight of the gun altogether to be about 10lbs., barrel 3 feet in length, and much stouter than any musket that has yet been made for our service. With this gun the following results were obtained at a target:

20 shots at 600 yards, elevation 1° 21′, gave a figure of merit of 6·96ins.								
20	„	800	„	2	18	„	„	11·85 „
2	„	1000	„			„	„	17.50 „

The cost of this weapon as a first class military arm, in large quantities, to be 6*l.* to 6*l.* 10*s.*

We shall now briefly describe the Mont-Storm rifle.

One of the special advantages claimed for this system of breech-loading is its applicability to any rifle constructed as a muzzle-loader; this is effected by simply cutting off about two inches and a half of the lower end of the barrel, and changing the part so cut off into a cartridge-chamber.

This cartridge-chamber turns back on a hinge on the upper part of the barrel (as will be observed in fig. 124), so that when it is in this position the cartridge is inserted from the rear, the powder forward, and the ball towards the stock (as shown by the letter B). Then, by

closing down the chamber (A) the powder comes into the reverse position and the ball forward (as in fig. 125, letters B and F);

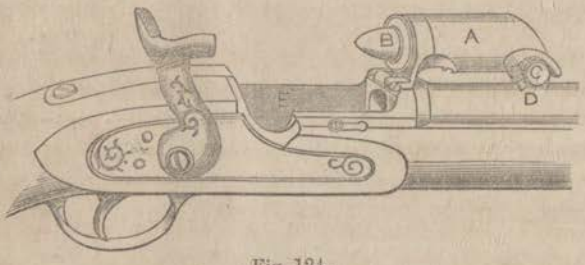


Fig. 124.

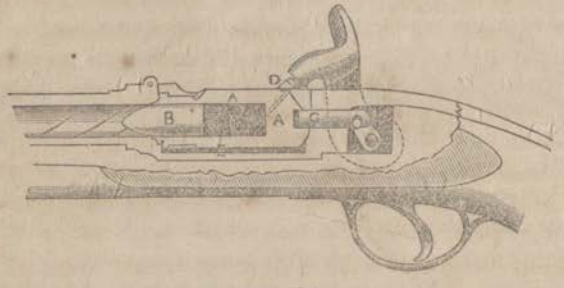


Fig. 125.

the front of the moveable chamber thus forming a joint with the barrel round the ball, and the rear fitting firmly against the breech part of the connection between barrel and butt; this connection forming, in fact, a hollow space or bed for the moveable chamber, which is unsupported on either side, and, without touching below, bears only against the breech. Fig. 124 represents an Enfield rifle converted into a breech-loader on this principle.

In order to prevent the leakage usual in these arms, a steel valve of peculiar construction is inserted into the chamber, so as to enter the place where it joins the barrel; the forward edge or circle of the valve, which is about the diameter of the bore, rests against the conical side of the barrel in front of the joint; and the hinder circle of the valve, which is of greater diameter, rests against the conical surface of the chamber behind the joint. The effect of this is that the elastic force of the gunpowder drives the valve forward and ex-

pands the two edges or circles of the valve against both chamber and barrel in proportion to their different diameters, so as effectually to prevent anything like leakage. A crank, having its centre upon the axis of the tumbler and its handle in a slot, holds a three-quarter inch bolt (see fig. 125, letter G); this is in the axis of the barrel, so that, when the gun is fired, the tumbler axis turning the crank, the handle drives the bolt about one-third of an inch into the breech part of the moveable chamber and utterly prevents its rising. The action of cocking the gun gives the crank a reverse motion, which at once unlocks the chamber from the breech and allows it to be raised by a force only sufficient to overcome the resistance of the spring which holds the chamber down under ordinary circumstances. The chamber can be raised when the gun is at half-cock, if required, an advantage which materially increases the security from accident.

On opening the chamber after firing, by throwing it back by means of its handle (fig. 124, letter C) to the top of the barrel, theexploded cap separates and falls from the cone (letter D) and the chamber, which may be loaded with powder and ball, without changing the horizontal position of the barrel, since it may be turned on the spring of the hinge so as to have its axis at right angles with the horizon, or with the axis of the barrel.

Fig. 125 represents the rifle as it would appear at the moment of firing, and explains the perfect solidity which is attained by the invention.

When the alteration of an ordinary rifle to one of these breech-loaders is effected scarcely any change takes place in its outward appearance; and, as in the case of the Westley Richards, it can be used either as a breech or muzzle loader, and has besides the additional advantage over its rival of not requiring any special ammunition.

The principle is an exceedingly simple one, and the patentees have particularly directed their attention to the Enfield rifles, both long and short, so that the Government, at a small expense, might convert the national weapon at once from a muzzle-loader to a breech-loader.

Just before the conclusion of the last Wimbledon meeting

an interesting shooting-match with this weapon took place. The conditions of the prize were very properly framed, so as to show the great advantage of the breech-loader in quickness of fire, while nothing was sacrificed in precision.

Each competitor was accordingly given the use of the butt for *two minutes*, and he was supplied with a Mont-Storm rifle and ammunition *ad lib.* with which he was at liberty to load and fire as fast as he pleased. The result is thus told in the pages of the *Volunteer Service Gazette:*

There were upwards of forty competitors, and the first prize was won by Ensign Starkie, of the Queen's (Westminster), who made 34 marks in 11 rounds. The second prize was won by Sergeant Drane, of the London Rifle Brigade, who made 32 marks in 13 rounds. One gentleman fired as many as 15 rounds in the time allotted, while another fired as few as 8. All fired from a sitting or lying-down position, and the advantage of loading a breech-loader was seen in a moment, when compared with the intolerably awkward military position of loading a long Enfield muzzle-loader from the knee. The rifleman with the breech-loader need never rise from his lying-down position, and consequently need never expose himself in the least to an enemy's shot, an enormous advantage in skirmishing and outlying or ambuscade work.

And the same journal adds:

This Mont-Storm contest, almost unobserved as it was, is all in the right direction. It showed the military qualities of a rifle in the highest degree—great simplicity—great quickness—great precision—and so sure are we that the breech-loader must ere long supersede the muzzle-loader that we gladly welcome any effort in this direction, and more particularly one that is, as in this case, so closely connected with the national arm.

A long series of experiments would be necessary to determine the comparative value of the two systems of breech-loading, as represented in the *Westley Richards* and *Mont-Storm* rifles. It is sufficient for us to have endeavoured to give a correct summary of their respective claims to favour

and ultimate adoption. For our own part, we think both are defective in one important particular, namely, in retaining the present system of igniting the charge. With a breech-loader that aims at increasing the rapidity of fire, it is absurd to retain the detached copper cap system, introduced at the beginning of the century. Surely, at the present day, with the Prussian needle-gun as a pattern to improve on, and with our boasted mechanical skill and knowledge of chemistry, something could be substituted for what is almost as great an inconvenience as the use of the ramrod itself. The latter involves eight motions in the platoon exercise, and the capping requires no less than six.

Those who come after us, at no very remote date, will doubtless smile at the soldier of 1863 with his eight rod-motions, and his six motions in capping, just as we now do in turning over the pages of some book of bygone wars, and meeting with the figure of a musketeer, arrayed in his panoply of harquebus with its forked rest, good and trusty rapier, clattering bandolier, and flask with its serpentine powder for priming the touch-hole, together with the oakum-match, which had to be well-blown before used for firing. Doubtless his figure was very picturesque; so were the ancient galleons of the times of Raleigh and Drake: but in these days of light and nimble Chasseurs and Zouaves, and 5-inch iron-plated steam ships, we delight in a very different picture.

Certainly the "get-up" of a soldier of the present day in England cannot lay claim to the picturesque; nor, unfortunately, does it make amends for that deficiency by its utility or adaptation to his work. A letter from the Author of the present book, which appeared in "The Times" of Dec. 28, 1860, contained the following remarks:—

The duellist, shooting with eyes blindfolded at an adversary a few

yards off, does not present a greater contrast to the intelligent rifle soldier of to-day than does the soldier of 1800; and yet, notwithstanding such a disparity, the *ancien régime* in every thing connected with the soldier's dress remains the same, unchanged; and the maxim enunciated by "the most finished gentleman in Europe," that "in a military dress a wrinkle was unpardonable, but a seam was admissible," is still the principle in vogue.

In ordinary life men dress themselves in accordance with their occupations;—thus the deer-stalker in Argyleshire adopts a very different costume from what he does in St. James's. Now, the soldier has, it may be said, to serve in St. James's, and at other times to perform rougher work than any deer-stalker; unfortunately, however, he cannot be provided with two costumes, and it would naturally therefore be supposed that his interests in the latter capacity, involving, as they do, his comfort and efficiency as a practical soldier, would be consulted; first but the very reverse is the case; appearance is the primary and efficiency the decidedly secondary consideration. The uniform is first modelled in conformity with St. James's, its tailors, and parade; and, as an instance of the manner in which its other requirements have to be supplied, the soldier at times applies his pocket knife to the seams of his breeches and tunic, so that he may perform his rifle practice with some degree of comfort and chance of success.

Activity is as essential to an army as speed is to a war steamer. The great secret of success in campaigning is in marching, or, as Marshal Saxe puts it, "in the legs;" but in modern warfare the soldier must do more than merely march well, for as soon as he finds himself at a distance of 1,200 yards or so from the enemy, he will have to continue to advance as a sharpshooter, combining in that capacity all the active agility of a mountaineer with the decision and foresight of a sportsman, till within 400 yards, say, of the enemy. Here a rapid concentration of troops must be made, when it still, perhaps, is left for the soldier either to scale a parapet or deliver a bayonet charge.*

* The crowning victory of Solferino was won by entire regiments and brigades being thrown into "loose order," and advancing in that formation till within some 300 or 400 yards of the enemy's batteries, when a rapid concentration took place, and then "a rush" made over the intervening ground. At Solferino the front of an army of 150,000 men extended over fifteen miles, whereas at Waterloo the front presented by 40,000 men was about one mile.

But, after this rapid and sustained advance, in what plight or condition would he be in to do this, clad as he is at present, with limbs fettered and cramped and encumbered with a weight of nearly 40lb.? The question naturally arises, then, "What manner of dress would be best suited for his fulfilling conditions such as the foregoing?" Let the soldier himself answer the question. On a sergeant being asked recently, in the presence of a "Select Committee," what dress he would prefer to fight in, he promptly answered, "In my shirt sleeves, yer honour." The reply pointed obviously to the great necessity existing for the adoption in the army of a looser and easier dress, formed of a lighter and more durable material, less like a strait-jacket in its restraint of motion, and more after the fashion of the famous Garibaldi loose shirt, or tunic. Such a dress, moreover, would at once meet the difficulty of extremes of climate; for, provided it was first adapted to the hottest climate in which our soldiers serve, it could easily, by a judicious system of under-clothing, be made suitable to the coldest.*

Perhaps a head-dress somewhat like that of the Sardinian Bersaglieri, a patrol-jacket like that of the Foot Chasseurs, or similar to what English sportsmen know as the Norfolk jacket, and loose trousers available at option as knickerbockers, like those of some of the Metropolitan Volunteers, will prove most conducive to the comfort, efficiency, and even the appearance of the rifleman of the future.

XXIX. It is with regard to our armaments and appliances of warfare precisely as with the other departments of human interest. The more we advance in civilization, the more are mechanical means substituted for manual labour—the lever, the pulley, the wheel and axle, the inclined plane, the wedge, and the screw spare the toil of the human muscle. It is the triumph of intellect. It is the fulness of man's

* It would be well too if the sash now worn by the officers were exchanged for a Russia-leather shoulder-belt with a pouch containing a field-glass attached to it. Any one who has been on service knows that with our long-range armaments a good field-glass is indispensable, in order that officers may perform their duty satisfactorily.

"dominion" over all the resources of the earth. A degree of creative power has been vouchsafed to him. He has formed the inert metals into a sort of living organism, and, as it were, imparted to it the most salient characteristics of his own intelligence.

Take the corn-field, for instance, at the present day. It is drained by steam-power—ploughed by the same. The crops are sown by a machine, and when Nature has done her share of labour, and the field stands in Autumn

Ripe with golden grain,

that grain is cut down by the reaping-machine—thrashed by a thrashing-machine—carried to town by a steam-engine, and, finally, is made into bread, "the staff of life," by steam.

We have sewing-machines that rival and excel in neatness of work the most delicate and fairy fingers of woman, shoe-making machines which will ere long abolish the cobbler's occupation, cow-milking machines that will emancipate woman from a most unseemly employment—in a word, machine upon machine—and all for the same purpose—to lessen or modify the hereditary curse upon mankind—"In the sweat of thy brow shalt thou eat bread."

XXX. A visit to our great factories of arms brings us face to face with the same wonderful development of machine-power. Every part of the rifle is, as we have before stated, made by a machine. The bullets are made by a machine. The percussion-caps are made by a machine, which forms the cap from a sheet of copper, primes it, and turns it out completely finished—all except the varnishing—which also is done very rapidly by another machine!

XXXI. Ever since the time when the great old poet sang of "Arms and the Man" there has been a ceaseless effort to make the former supply the place and do the work of the

latter. More especially has this endeavour become manifest during these last few years. We have breech-loading ordnance with terribly destructive power at prodigious distances. We are about to have guns of colossal dimensions, worked and trained in Coles's cupolas. Repeating rifles have been constructed to deliver individually the fire of a whole section of a company; and a certain American has devised a war-engine to deliver a fire equal to that of a whole company or even a battalion!

From the past and the present we may confidently predict the future, and we do not hesitate to say that just as the old smooth-bore flint musket, with its great windage, made way for the percussion and grooved rifle system, and the latter is being superseded by the *Whitworth*, so, in like manner, must the last eventually succumb to some perfect form of *breech-loading* rifle.

> Heaven from all creatures hides the book of Fate—
> For all perfections man must ever wait.

FINIS.

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